the emc journal

Issue 104 January 2013

ISSN 1748-9253

Know Your Standards
By John Woodgate
See page 18

Eight Pages of Banana Skins
See page 8

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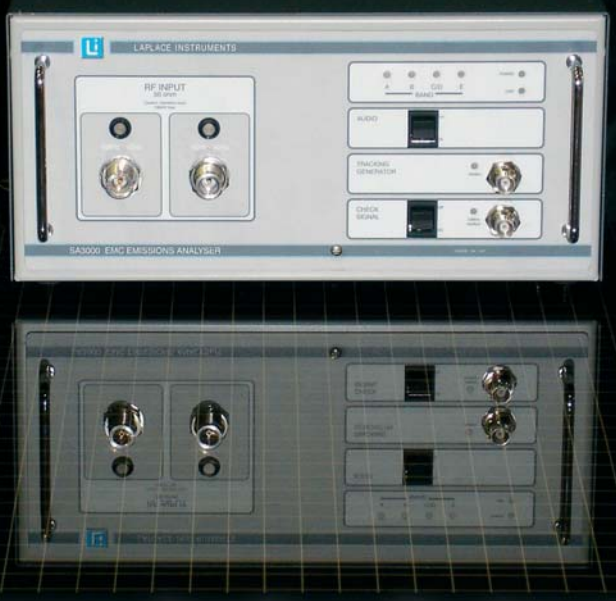

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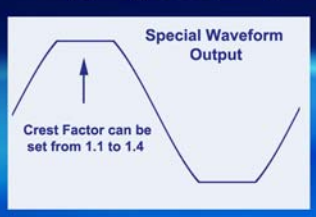
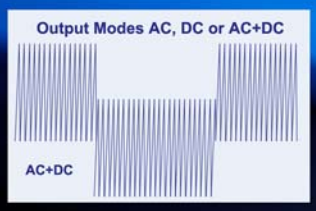
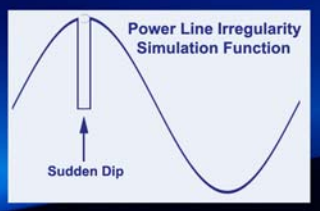
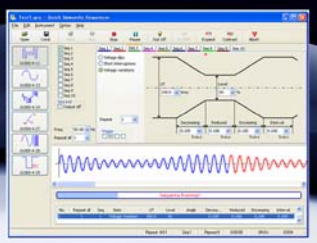
AC POWER SUPPLIES









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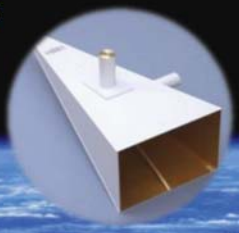

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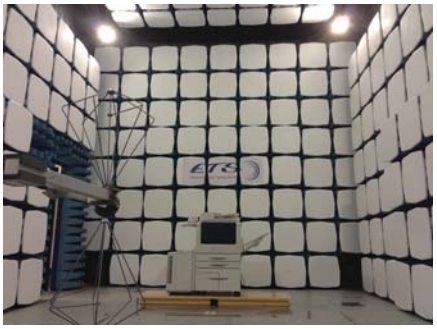
News

Electromagnetic Testing Services unveil New 3m Semi-Anechoic Chamber

Electromagnetic Testing Services (ETS) are pleased to announce that the installation and calibration of a new 3m Semi-Anechoic chamber at their facility near Stebbing, Essex, has recently been completed.

The new chamber, which is housed in a newly built extension, greatly enhances the facilities at ETS and means that full compliance radiated emission (30MHz – 18GHz) and radiated immunity (80MHz – 6GHz) measurements can now be performed without the need of the Open Area Test Site. The chamber has a large 2m wide by 2.1m tall access door, 2m diameter turntable and floor loading of 1000kg/m^2. This means that larger EUT's, which previously could only be tested on the OATS, can now be handled with relative ease and in the comfort of an indoor environment.



The installation of the new chamber, which was designed, manufactured and installed by Rainford EMC Systems, began in mid October and, following calibration, was completed in late November. Since early December, the chamber has been in constant use by customers.

George Vasilla, Managing Director of ETS commented that "We chose to work with Rainford EMC Systems on this new chamber due to their experience and track record of providing chambers. Throughout the entire project, from concept to completion, we had a really good relationship with them and, were able to continue our normal day to day operations with only minimal disruption. All the staff at ETS, and the customers who have so far used the new chamber, are very impressed with the results and of course it is allowing us to grow and develop the business."

REMC's European Sales Manager, Paul Duxbury, added "We were really pleased that ETS chose to work with us on this project – this new chamber represents a significant investment and development of their capabilities. It is one which will bring them and their customers benefit for many years."
www.etsemc.co.uk; www.rainfordemc.com

TÜV SÜD Product Service appointed by CESG to support National Security Certification Scheme

TÜV SÜD Product Service has been appointed by CESG, the UK's National Technical Authority for Information Assurance, as a TEMPEST Test Facility under the CESG Formal TEMPEST Certification Scheme (CFTCS).

TÜV SÜD Product Service has been evaluated according to the criteria of the CFTCS and has met the standard to be accredited to evaluate and certify products on behalf of CESG. The CFTCS ensures that compromising emanations from Information & Communications Technology (ICT) equipment are within the limits defined in NATO standards.

As well as submitting products for testing by TÜV SÜD, manufacturers will have to undergo regular TEMPEST production audits to achieve and maintain certification. Previously, CESG was the only UK organisation able to certify products. Now that TÜV SÜD is one of three accredited testing facilities in the UK authorised to issue TEMPEST Certificates, the certification process is faster and more agile.

"Jean-Louis Evans, Managing Director of TÜV SÜD Product Service, said: "Our appointment as a TEMPEST Certification Test Facility is testament to TÜV SÜD's pedigree in TEMPEST and EMC conformance testing. The combination of our impartiality, familiarity with an extensive range of ICT products, experience of working with many governments and NATO, as well as our international presence makes our expansion into the TEMPEST certification domain a simple transition."

About TEMPEST
TEMPEST is a general term for naturally occurring and unintentional electromagnetic emanations from equipment and systems which can result in the spatial and conducted recovery of sensitive information from a distance. TEMPEST certification is based on testing to demonstrate conformity with verifiable and repeatable standards specified by CESG, and is underpinned by an effective quality management system.

The new scheme seeks to achieve assurance based on compliance at every stage of a product's life, from its initial design onwards. It supports the Government's UK Cyber Strategy, ensuring that TEMPEST services comply with the updated NATO SDIP-55 standard and is compatible with the EU's IASG4-04 standard.
www.tuv-sud.co.uk

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Secretariat for EMCIA

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The EMC Journal

Free to readers worldwide
January 2013- Issue No. 104
Published every other month
First Issue March 1995

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News and Information

AR Europe announces new distribution agreement with Eastern Optx

AR Europe is proud to announce their new exclusive distribution agreement with Eastern Optx, a New Jersey based company that designs and manufactures fibre optical delay systems. This new product line includes radar target simulation systems, radio altimeter test sets and channel replicators.

The Eastern OptX products are available for the European market through the AR Europe sales channels from December 1st 2012.

At present this agreement applies to the entire AR Europe channel excluding the German and Italian markets.

With its fibre optical delay line technology, Eastern OptX provides an efficient solution to the market where transmission delays are required without having the need to perform these tests in real field situations.

The fibre optical technology has a many great advantages, one of the most important is the enormous bandwidth (40 GHz) in which signals can be delayed. This allows users of broadband systems such as frequency hopping or wide-band multi channel radar systems to receive, delay and retransmit the received signal without tuning replication systems.

As most fire and control radar systems are looking for incoming targets, the Eastern OptX delay lines can be fitted with Doppler modulators that provide the reflected pulse with a simulated speed. Without this option, many of these systems neglect echoes. As the target simulator uses low-loss optical fibre to create the distance between the radar and the target, there is almost no difference between the amplitude of a close by and far away target reflection. To create a more real world simulation, the system can be fitted with an optional variable attenuator that varies the level of reflection as a function of the distance.

Another solution provided by Eastern OptX is the radar altimeter test set. This is also a fibre optical based system and is used in the calibration procedures for altimeters. This products wideband capabilities offer some great advantages especially in cases where the new LPI (Low Probability of Intercept) Radio Altimeters are used in Military applications such as helicopters and UAVs. These wideband, spread spectrum like signals can easily be handled by Eastern OptX delay lines where IF based system suffer in frequency agility.

To test radio network connections, Eastern OptX's channel replicator system offers a simulation capability for a multi-radio network allowing reliability testing of the communications network for propagation effects and to test multi vendor interoperability. For further information contact Mark Reeve on **+44 (0)1908 282766, mreeve@arworld.us**

emcia Member

New Manager for Chomerics

Chomerics Europe - a division of Parker Hannifin, has appointed Tiberius Recean to the position of Automotive Specialist. 44-year old Recean has worked for Chomerics Europe for six years as a Territory Sales Manager in Germany.

The creation of the new role is in recognition of the growing importance and relevance of shielding and thermal management materials to the automotive market. As the magnitude, variety and complexity of electronic systems on passenger vehicles continues to increase, so does the need for advanced and innovative materials to manage EMI/RFI and heat such as those developed and manufactured by Chomerics.

In his new role, Tiberius will be responsible for developing and managing the company's activities and business in key automotive customers with primary focus in Germany. He will also provide support to coordinate automotive projects with Chomerics divisions on a global basis.

Before joining Chomerics Europe, Tiberius worked for the German automotive cable and wiring harness manufacturer – LEONI AG. Prior to that he developed his extensive technical knowledge and understanding of the automotive electronics market working as an electrical engineer for EMI.

emcia Member

New Business Unit

Pentair has formed a new global business unit called Pentair Equipment Protection to bring together its three renowned brands of Schroff, McLean and Hoffman. This umbrella unites all components, systems and service schemes related to the protection and cooling of electronics and electrical assemblies, so customers now have a very large range of products, know-how and services available to them.

For more than 50 years Schroff has been associated around the world with electronics packaging solutions for test and measurement, industrial automation, defence, transportation and communications systems. Products range from cabinets, cases and subracks to power supply units, backplanes and complete systems for a variety of bus-based specifications.

Similarly, McLean has enjoyed a reputation for over 30 years as a source of quality cooling products, including fans, air conditioners and custom electronics cooling equipment. The Hoffman brand is known in the market for enclosure systems providing secure and reliable protection to sensitive electrical and electronic control systems in industrial applications.

For more information, visit **www.pentairequipmentprotection.com.**

An Open Invitation To Our Readers

Hursley EMC Services have relocated a few hundred yards to a new 10,000 sq foot purpose built laboratory in Chandlers Ford, Hampshire.

They are planning an Open Day event in March (date to be confirmed) for all interested parties to view their new improved facilities.

Readers of the EMC Journal are therefore invited to contact Hursley EMC, if they wish to attend.

For further information and to register your attendance please contact Anna Pettit on 02380 271111 or e-mail anna@hursley-emc.co.uk

News and Information

University of Oxford
High-speed Digital Engineering and EMC
June 2013

Led by Dr Howard Johnson, author of "High-Speed Digital Design - A Handbook of Black Magic", this programme offers a number of short courses delivered by some of the world's leading digital design experts.

Celebrating 20 years of High-Speed Digital Engineering at Oxford.
Dr Howard Johnson will return to Oxford for the 20th and final time in June 2013 to teach his courses

- High-Speed Digital Design
- Advanced High-Speed Signal Propagation
- High-Speed Noise and Grounding

This will be the last time Dr Howard Johnson's courses are available in Europe.

For digital logic engineers, system architects, EMC/EMI specialists, signal integrity specialists, technicians, printed wiring layout professionals, applications engineers, PCB design engineers, system designers, test engineers and anyone who works with digital logic at high speeds (20MHz to 20GHz and beyond).

- High-Speed Digital Design (17-18 June 2013)
- Advanced High-Speed Signal Propagation (20-21 June 2013)
- High-Speed Noise and Grounding (24-25 June 2013)
- Printed Circuit Board Design for Real-World EMI Control (25-26 June 2013)
- Advanced EMC: Fullwave Modelling for EMC and Signal Integrity (27-28 June 2013)
- Introduction to Data Converters (2-day course - June 2013 - dates to be confirmed)
- Advanced Data Converters (2-day course - June 2013 - dates to be confirmed)
- Electronic Product Design and Retrofit for EMC (2-day course - June 2013 - dates to be confirmed)
- High Frequency Measurements (probes and equipment used in Signal Integrity and EMC work) (2-day course - June 2013 - dates to be confirmed)
- EMC and ESD Lab Techniques for Designers (troubleshooting to proactively avoid field or compliance problems) (1-day course - June 2013 - date to be confirmed)
- Advanced Troubleshooting Techniques for Circuits and Systems (1-day course - June 2013 - date to be confirmed)
- Power Distribution Design (2-day course - June 2013 - dates to be confirmed)
- Suspect Counterfeit Detection Avoidance and Mitigation (2-day course - dates to be confirmed)

This programme of short courses for professionals working in digital engineering and EMC-related fields is held each year in June, with some courses repeated in November/December each year. It is the only public training programme in Europe to feature courses by Dr Howard Johnson.
For more information go to: **http://www.conted.ox.ac.uk/courses/professional/staticdetails.php?course=216**

8th CST European User Conference

The 8th CST European User Conference will be held in Stuttgart, Germany, April 23–25, 2013. This conference offers you a great opportunity to advance your simulation skills and exchange ideas with other users.

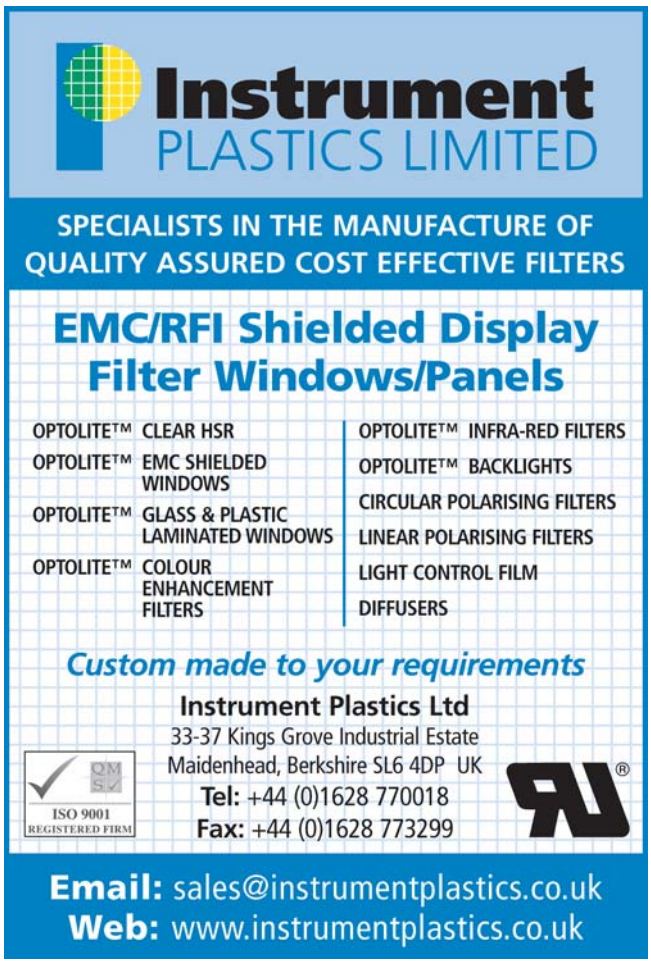
More information about this event, including the preliminary agenda and online registration, is available at **www.cst.com/euc**

Call for Contributions
We are interested in your work with the CST STUDIO SUITE product family. If you would like to contribute to this event, share your experience, and discuss your questions in a forum of your peers, please submit a text abstract of between 100 and 200 words to **events@cst.com**

CST honors your contribution to the EUC by offering a discount of 50% on the attendance fee for an accepted presentation. Please note that in order to qualify for this discount, the final abstract has to be received by 28.02.2013 and the finished presentation by 31.03.2013.

EMC/China 2013
23-25 October

EMC/China 2013 will be held from 23 - 25 October 2013 at Shanghai Everbright Convention & Exhibition Center.
www.emcexpo.com



Banana Skins...

Editor's note: I receive many potential Banana Skins, and no doubt they are just the topmost tip of the EMI iceberg. Keep them coming – but please don't be disappointed if your contribution doesn't appear for a while, or at all. **A special New Year edition of Banana Skins this time – 8 pages!**

740 EM environment limitations in the safety information for a new smartphone

Do not use your device near other electronic devices

Most electronic devices use radio frequency signals. Your device may interfere with other with other electronic devices.

Do not use your device near a pacemaker

- Avoid using your device with a 15cm range of a pacemaker, if possible, as your device can interfere with the pacemaker.
- To minimise possible interference with a pacemaker, use your device only on the side of your body that is opposite the pacemaker.

Do not use your device in a hospital or near medical equipment that can be interfered with by radio frequency

If you use medical equipment, contact the equipment manufacturer before using your device to determine whether or not the equipment will be affected by radio frequencies emitted by the device.

If you use a hearing aid, contact the manufacturer for information about radio interference

The radio frequency emitted by your device may interfere with some hearing aids. Before using your device, contact the manufacturer to determine whether or not your hearing aid will be affected by radio frequencies emitted by the device.

Turn off the device in potentially explosive environments

Turn off the device in potentially explosive environments instead of removing the battery

- Always comply with regulations, instructions and signs in potentially explosive environments
- Do not use your device at refuelling points (petrol stations), near fuels or chemicals, of in blasting areas.
- Do not store or carry flammable liquids, gases, or explosive materials in the same compartment as the device, its parts or accessories.

Turn off your device when on an aircraft

Your device may interfere with the aircraft's electronic navigation instruments.

Your device may interfere with automotive equipment

Electronic devices in your car may malfunction, due to radio interference from your device. Contact the manufacturer for more information.

Do not store your device near magnetic fields

- Your device may malfunction or the battery may discharge from exposure to magnetic fields.
- Magnetic stripe cards, including credit cards, phone cards, passbooks, and boarding passes, may be damaged by magnetic fields.
- Do not use carrying cases or accessories with magnetic closures or allow your device to come into contact with magnetic fields for extended periods of time.

(Taken from the "Safety Information" section of the User Manual of the latest model of a popular and highly-regarded smartphone, purchased in September 2012. Notice that the smartphone user is required to be knowledgeable about EM environments and potentially explosive atmospheres, and to be continually monitoring their EM environment for magnetic fields, with no maximum level specified. Also, the requirement to not use the phone "near other electronic devices" gives no guidance on what is too near. If the word "near" means the same as in the normal EMC emissions and immunity standards that are used to provide compliance with the EMC Directive, this effectively means the user instructions do not permit the smartphone to be used in any modern home, office or train.

741 Action taken against Alternative "Energy Medicine" devices

After reports in the national media, spearheaded by the Seattle Times, about the widespread fraud and health perils inflicted on American patients by the makers of electrical devices touted as miracle cures for serious diseases such as cancer and AIDS, the Food and Drug Administration (FDA) has banned importation of the EPFX.

This desktop device is manufactured in Hungary by William Nelson, a federal fugitive who fled the country in 1996 when faced with felony fraud charges. Another electrical device under investigation is the PAP-IMI (Pap-Ion Magnetic Inductor), a 260-pound electric pulsing machine that's been linked to patient injuries and deaths. The latter is the invention of Prof. Panos Pappas, a Greek inventor and non-physician. Both these devices are based on the belief that the human body consists of energy fields and that altering those fields can improve or restore health. Apart from the obvious dangers of subjecting the ill and injured to electrical charges, physicians note the perils of delaying or rejecting medical care that might have helped.

Now the U.S. House of Representatives, Committee on Energy and Commerce's, Subcommittee on Oversight and Investigations, has instructed the FDA to provide all relevant records on these devices, their makers, and distributors. Of particular concern, is the loophole posed by the use of Institutional Review Boards (IRBs). Makers of both these devices appear to have hired private companies of medical professionals (IRBs) to evaluate their devices and to qualify them for use on patients. Examination by an IRB is not the equivalent of FDA approval, but can be used by the unscrupulous to defraud the gullible or desperate. View the entire Congressional letter online.

(*Taken from: 'FDA, Congressional Sub-Committee Take Action Against Alternative "Energy Medicine" Devices', Interference Technology eNews, December 27, 2007, www.interference technology.com. For more information, also see "Congress Asked to Investigate Quack Devices - Device Watch", www.devicewatch.org/reg/inslee.pdf; http://en.wikipedia.org/wiki/List_of_topics_characterized_as_pseudoscience; http://www.camlawblog.com/promo/speaking/legal-boundaries-and-ethics-in-energy-work.)*

742 Radio Mast EMI Case Headed to Court

A farmer in Purnim, a township in Victoria, Australia, is on his way to the Supreme Court in his battle against broadcasting company Ace Radio over the location of transmission masts. Independent testing carried out by EMC Technologies showed electromagnetic interference was occurring in the house, and the farmer claims the radio towers are interfering with his telephone, fax, computer and radio and affecting his animals.

PURNIM farmer John Howard is on his way to the Supreme Court in his battle against Ace Radio and Moyne Shire Council over the location of radio masts. Mr Howard, who lost a Victorian Civil Administrative Tribunal (VCAT) appeal on the matter, has been granted leave to appeal to the Supreme Court of Victoria. Two Ace Radio transmission masts on a property opposite Mr Howard's house on Blighs Road were built 126 metres and 58 metres closer to his house than the original planning permit specified. The towers are also 11 metres taller than the original specification and have 15 guy wires instead of eight. Permission to vary the position was given verbally by a Moyne Shire officer. Ace Radio, which owns Coast FM and 882 3YB, and Moyne Shire Council are named as respondents in the case, due to be heard in May. Mr Howard has a document from the Minister for Planning Justin Madden that says: "Changes to a planning permit can not be verbally approved under Victorian planning legislation. "The permit was retrospectively amended on June 16 this year, after the towers had been built, following a review by VCAT. Mr Howard said the towers were causing interference with his telephone, fax, computer and radio as well as affecting his animals. The revised siting of the masts put them closer to power lines that connect to Mr Howard's house, which he believed to be a factor in the interference. Independent testing commissioned by Ace Radio and carried out by EMC Technologies, showed electromagnetic interference was occurring in the house. Mr Howard said his bore pump had blown up twice and an electric fence had been damaged during thunderstorms since the installation of the masts. The report by EMC Technologies said the ground current associated with lightning strikes could affect equipment connected to the mains. Mr Howard wants the towers moved to their originally planned positions or his house and sheds relocated. Moyne Shire has estimated the cost of moving the buildings at $880,000. Mr Howard said the battle had already cost $500,000."I stand to lose the farm over this," Mr Howard said. "I have done nothing wrong and I'm determined to see that the council is held responsible for the action of its officer who gave verbal consent when he had no right to do so." Moyne Shire chief executive Brett Stonestreet declined to comment.

(Taken from Interference Technology magazine's on-line newsletter, http://72.29.76.194/~interfer/radio-mast-emi-case-headed-to-court/, 12/16/09 03:37 PM, and from the original article from The Standard newspaper: "Supreme Court Date Set", by Steve Hynes, Nov. 25, 2009, 10:33 a.m. http://www.standard.net.au/story/740348/supreme-court-date-set/.)

743 Interference Stymies Radio Test

The BBC has released a report on its year-long test of digital medium wave (DMW) radio (or digital radio mondiale (DRM) radio) that is reported to offer a more robust signal that carries for greater distances than analog radio broadcasting.

The trial was held in southwest England using the frequency of BBC Radio Devon and was codenamed project Mayflower.

Volunteer listeners reported favorably on the quality of daytime broadcasts, but attempts at broadcasting after sunset were another story.

Nighttime changes in the atmosphere allow for distant off-shore signals to interfere with DRM, which in turn ceases to decode the signal causing an interruption in reception.

BBC spokesman said that the problem would require re-planning the transmission network and/or the building of new transmitters.

Industry analysts have concluded that the switchover from analog radio broadcasts is still some time away. The entire 11-page report on Project Mayflower has been posted online: http://downloads.bbc.co.uk/devon/pdfs/project-mayflower-summary-report.pdf.

From the official report:
Given the additional interference to medium wave services from distant interferers which is apparent at nighttime, the nighttime coverage was always expected to be smaller than the daytime coverage. Indeed, the DRM coverage at night is larger than the equivalent 'clean' AM coverage at night.

It is important to note that the frequency we were using for DRM at Plymouth is particularly susceptible to interference from distant transmissions, although it is not atypical of the situation that occurs on many AM frequencies assigned to BBC Local and network radio in the UK. In some areas, the frequency allocated may be very much clearer of interference and so the difference between daytime and nighttime reception will be less marked: it is possible that the frequency allocated to BBC Radio Scotland (810 kHz) is one such example.

However, a difference between the daytime and nighttime coverage of the transmission will always present a problem, even if the nighttime coverage is greater than the claimed AM coverage at the moment. This is for three principal reasons.

First, the enormous area which appears to be served by DRM during the day means that the contrast between the nighttime and daytime coverage is even greater and potentially affects even more people. Mediumwave transmitters are typically planned on the edges of cities, so that the main centre of population is comfortably within the nighttime coverage area of the AM. However, if DRM is capable of serving a widearea then it stands to reason that neighbouring centres of population – previously outside both daytime and nighttime coverage – will now be daytime only.

Second, whilst the nighttime coverage of DRM is greater than the equivalent 'clean' AM coverage, it is apparent that the technical limit of AM coverage is not the same as the limit at which listeners will stop listening to it. Thus, listeners will tolerate much more crosstalk from interfering sources than is catered for in international planning standards, even

more so if it is content that they especially wish to hear.

Similarly, listeners will listen to fieldstrengths well below the international limits even if the result is audio which is covered in static and noise. For this reason, the area in which listeners expect to be able to receive AM at night is almost the same as the area in which they can receive it during the day; and is very much bigger than the technical limit of AM coverage.

Third, the failure mode of DRM is – as with all digital systems – dramatic. The transition from working perfectly to not working at all is fairly sudden, even considering that DRM is designed to provide a measure of graceful degradation for longer than some other digital systems. Thus, listeners who previously received a degraded, interfered with AM service at night now received nothing. At other times, given the dramatic fluctuation in interfering signal strength, listeners found the radio services dropping out – or burbling, or becoming 'metallic' in sound – and taking some while to restore, despite any actions they took.
(Taken from" Interference Stymies Radio Test" in Interference Technology Magazines on-line newsletter: http://72.29.76.194/~interfer/interference-stymies-radio-test/, 05/27/09 04:36 PM, and from http://downloads.bbc.co.uk/devon/pdfs/project-mayflower-summary-report.pdf.)

744 **James C Klouda, RFI expert**
Jim, it will be recalled, recognized at a very early stage the need for testing electronics and receivers for radio frequency interference.

Interestingly, his first real world application of his EMC background was at the start of his EMC career in the early 1950's. He had just graduated from the Illinois Institute of Technology and took a job at Chicago Aerial Survey in Chicago. There was interference to a new aerial camera aboard a US Air Force bomber. The camera caused interference to the bomber's autopilot programming.

Jim was called and after review of the situation had shielding installed by the manufacturer's camera. This solved the problem and there were no further EMC issues with the autopilot system. From that point on he became the RFI expert.
(Taken from "Completed Careers", by Don Hierman, Associate Editor, IEEE Electromagnetic compatibility magazine, Volume 1, Quarter 3, 2012, page 58, http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=06347052.)

745 **Beer Blacks Out TV**
In a reprint of a United Press International Dispatch (dated May 31, 1962), it was stated: "Rochdale, England – Television sets in the neighborhood of the Dog and Partridge pub are back to normal now that they discovered that the trouble was caused by beer. Engineers found interference was caused every time the barkeeper drew a beer from one of the pub's seven spigots, so they 'neutralized' the spigot."
(Taken from "50-25-10 Years Ago: A Review of EMC Society Newsletters, by Dan Hoolihan, Associate Editor, IEEE Electromagnetic compatibility magazine, Volume 1, Quarter 3, 2012, page 22, http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=06347047.)

746 **Oops, that was a 1,550 Amp Lightning test, not 150 Amp!**
Pat André of André Consulting, Inc. shared a story that reminds us that it is good practice to ask more questions, even if the answers seem obvious, to get the needed solution. As usual, the story is told from Mr. André's perspective.

"While consulting for a client, I was approached by a different company who was performing lightning testing at the same laboratory as my client's. This company was having a great deal of difficulty passing a lightning test. When I saw the unit and the test they were trying to pass, my first question was, "Can you shield these cables?" I was told no.

The unit was small, and although the test levels were not very high, the size of the transient suppression required to pass this test would not have fit inside the box. So we tried several other filtering techniques, with very little success. Therefore, in desperation, I questioned the client more about the shielding issue, with the thought of approaching their customer and requesting if we could shield the signal cables in question.

They told me it was not the customer who said they could not shield the cables, but another consultant - who was worried about "ground loops" (What?). Once I was clear on this, we went to their engineering laboratory, grabbed some overbraid, and shielded the signal lines, assuring both ends of the shield were well bonded to the connectors.

Back at the testing laboratory, the test engineer and the head engineer from my client's company were both weary after many failures. So, starting at a low level, 100 amperes injected current, they slowly worked their way up to the test limit of 150 amperes.

After passing at 140 amperes, the test engineer said, "Okay, are you ready for 150 amperes, the full test level?" We all assured him that we were ready. When the test engineer initiated the test, we immediately heard a large BANG! We watched in stunned disbelief as sparks flew and smoke escaped from each connector.

My client looked like he was ready to change careers, hanging his head in defeat. At that point, the test engineer turned to me and apologetically said, "Oops. That was 1,550 amperes."

Now that I knew the reason for the sparks and smoke, I turned to the customer engineer and said, "Wait, this may be okay. Check the unit. Is it still working?" After a moment, he said, "Yep. It's working fine!"

I told the customer engineer that I could get off his payroll at that point, since his unit appeared to pass at 10 times the test level. But, he would have none of that. He told me that I was to sit there and watch the rest of the four hours of testing. The rest of the morning was quiet, and I almost felt guilty for invoicing them for that time. Almost. I was just glad I pursued the shielding question."
(Taken from "Chapter Chatter" by Todd Robinson, Associate Editor, IEEE Electromagnetic compatibility magazine, Volume 1, Quarter 3, 2012, page 8, http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=06347045.)

747 **Nikon D800 Wireless Memory Card Issues Caused By RF Interference**
Eye-Fi, the manufacturer of SD memory cards and SDHC cards with Wi-Fi, has released a solution to an issue that prevented their cards from working with the Nikon D800 and D800E.

In early October, Eye-Fi confirmed a

compatibility issue that impacted the use of Direct Mode in the Nikon D800. Though the two products were marketed as compatible, consumers were "unable to use Eye-Fi's Direct Mode, and in some cases unable to use any of the card's Wi-Fi capabilities as all."

According to an Eye-Fi representative, the company determined the issue was caused by interference emanating from the unique USB 3 connector inside the camera. The update provided by Eye-Fi changes the card's broadcast channel to prevent further interference issues.

"By default, Direct Mode broadcasts on channel six. In the D800, due to noise that's coming from the USB 3 interface, we needed to broadcast on channel 11," Ziv Gillat, Eye-Fi co-founder, said.

More details from Imaging Resource:
Makers of the Eye-Fi wireless memory cards this week released a fix to an issue that kept their cards from working fully with the Nikon D800 and D800E. The problem, according to an Eye-Fi representative, is caused by noise coming from inside the camera, specifically from the D800's unique new USB 3 connector. Posted on Monday, the update works around the issue by changing the card's broadcast channel.

Eye-Fi's Direct Mode allows a direct connection to devices that can't create a Wi-Fi hotspot.

Early last month, reports surfaced of an issue with Eye-Fi's WiFi-connected SD cards, when used in the full-frame Nikon D800 and D800E digital SLRs. Although the two products were said by their makers to be compatible, users found themselves unable to use Eye-Fi's Direct Mode, and in some cases to use any of the card's Wi-Fi capabilities at all. Now, Eye-Fi has issued a fix, and a statement from Eye-Fi co-founder Ziv Gillat published by The Phoblographer suggests that radio frequency interference from the D800 body is to blame.

"By default," said Gillat, "Direct Mode broadcasts on channel six. In the D800, due to noise that's coming from the USB 3 interface, we needed to broadcast on channel 11."

Nikon's D800 is the first DSLR with USB 3.0 connectivity, but Eye-Fi has discovered that it can interfere with the default channel used by its Wi-Fi connected flash cards.

Although the problem prevented use of Direct Mode with the D800 and D800E bodies, there was no risk of data loss; images were still written to the flash card, even if they could not be transmitted wirelessly.

Some users have reported more general problems with Wi-Fi beyond the Direct Mode, though, and Eye-Fi's fix doesn't specifically address this. (Nor could problems in other modes be addressed by firmware, if the problem is indeed caused by RF interference on specific channels, as the channel is set by the access point, not the client.) Of course, if you are having problems beyond Direct Mode and have access to the router, it would seem logical that configuring it to use channel 11 - if too many adjacent networks aren't already using that channel - would be likely to help the situation.

More details on the firmware update can be found on the Eye-Fi website.
(Taken from www.interference technology.com nikon-d800-wireless-memory-card-issues-caused-by-rf-interference/, 12/19/2012, and also from Imaging Resource: "D800 compatibility problems caused by RF interference, says Eye-Fi", by Mike Tomkins, posted Wednesday, November 21, 2012 at 7:31 PM EST www.imaging-resource.com/news/2012/11/21/d800-compatibility-problems-caused-by-rf-interference-says-eye-fi. Also of interest is the Nikon Rumors site: http://nikonrumors.com/2012/11/20/eye-fi-cards-now-compatible-with-the-nikon-d800-camera.aspx/.)

748 "Survival of the Fittest" – EMC in Electric Power Substations

When a short circuit occurs in a transmission substation (usual definition – voltages above 100,000 volts), the resulting fault current is spectacular. In some substations, it may be as high as 80,000 amperes.

Let's assume the fault was caused by the flashover of a porcelain insulator supporting a section of the high voltage power line a few towers away from the substation, due to a buildup of sea salt. The protective relays monitoring this transmission line detect this abnormally high current, and close their "trip" contacts – which then cause both the high voltage circuit breakers connected to this transmission line to open – and thus "clear the fault".

But while the fault exists, this high current is flowing from the tower to ground, then through the earth back to the substation. And since there is a finite (non-zero) resistance to "true earth ground", this causes the entire substation ground matt voltage to rise. However, this is a 60 Hertz voltage, and adequate insulation - in control circuits and electromechanical protective relays - for this well recognized "ground potential rise" has been defined for years in protective relay standards (e.g. ANSI C37.90).

It is the time to "clear" (interrupt) high fault currents - and particularly three phase faults - that determine how long a given electric utility (or an interconnection of several utilities) can remain stable after the fault has cleared.

In the late 1950s, high voltage circuit breakers began being manufactured with a guaranteed fault clearing time of two cycles (at 60 Hz) or less - and at a modest premium over three cycle breakers. This was a substantial improvement, and many were installed. But due to the inertia of its moving parts, there are finite limits to the operating speed of electro-mechanical protective relays. So with the invention of the transistor, there was an immediate interest in utilizing these "static" (no moving parts) components in new designs of transmission line protective relays, as they held the promise of saving another full cycle (16.67 milliseconds) off the overall operating time of the relay/circuit breaker combination.

Beginning in the late 1950s, General Electric and Westinghouse designed and built "static terminals" whose designs were thoroughly tested on model power system simulators. These simulators were vital "proof testing" tools to examine all varieties of single phase, double phase, line-ground, line-line, and three phase faults at various distances on two and three terminal lines. They did operate

much faster, and were beginning to be widely deployed. Then the transistor components in these "static terminals" began to fail – and with no apparent connection to any high current (short circuit) event at or near the substation. What a mystery!

Even more troubling was the fact that the failures were occurring on static terminals in relay control houses, often many feet/meters from the high voltage bus work. The failures were in the transistors connected to the VT, CT, and DC control conductors in the control house.

Slowly energizing or de-energizing just one of the capacitance elements (e.g. capacitor banks, coupling capacitor voltage devices, circuit breaker bushing capacitance) as shown in Figure 1 can create the oscillatory Surge Withstand Capability (SWC) transient. Because of the slow moving switch, the result is a sequence of flash-overs (energizing) followed by decaying oscillations to zero, then repeated until the switch is fully closed or open.

The rise time was in the micro-second range to a peak of several kV, the oscillations in the 1 Megahertz range decaying to 50% in a few cycles, with repeats at many times per second. This transient now is a part of IEEE standard C37.90.1 as the "oscillatory SWC test". From its beginning in 1974, the required peak voltage for this transient test has been 2.5 kV at all locations (indoor and outdoor).The comparable IEC standard (IEC 60255-28) requires this level for outdoor installations, but only 50% of that for indoor installations.

In the mid 1970s, at Philadelphia Electric's Eddystone Generating Station, a control technician was beginning the task of tuning the excitation system of one of the 380,000 kW supercritical steam turbine-generators. He was bent over the excitation system's control panel, and his 5 watt "walkie-talkie" transceiver was clipped to the belt at the center of his back. When he pressed the "Push to Talk" button on his microphone, his back (and the radio's antenna) was much less than 1 metric meter from a static transformer differential relay for the unit's step-up transformer. The relay had been designed to meet the then current RF immunity level in IEEE Std C37.90.2 (10 volts/meter).

That standard also included, in boldtype, a "Caution" statement alerting users to maintain a separation distance of at least one (metric) meter between a transceiver's antenna and any sensitive equipment. However, with less than half that separation distance, the RF field strength at the relay was much higher than 10 V/m. The relay incorrectly operated, and the turbine-generator tripped off line. The next revision of IEEE standard C37.90.2-1995 raised the required immunity level to 35 V/m – which is the RF field strength from a 5 watt transmitter's antenna at a distance of 50 centimeters (~ 6 inches) where it remains today.

In spite of repeated attempts by electric utility engineers who are members of their county's IEC TC 95 delegation, the immunity level specified in IEC standard 60255-26 "for measuring relays and relay systems" remains at 10 V/m.

In the late 1970's, a vacuum tube based automatic synchronizing relay failed catastrophically. More specifically, a transient of unknown origin had caused a hole to be burned through the glass envelope of a vacuum tube in its operating circuitry.

The failed relay was mounted on the control panel for a barge mounted peaking gas turbine-generator at the Consolidated Edison's Gowanus Generating Station. There was no voltage on the barge higher than 15 kV, and even so, the relay design had been tested and met the oscillatory SWC test (now in IEEE Std C37.90.1). William E. Kotheimer was able to replicate the failure; he burned a similar hole in the vacuum tube's glass envelope. But this time, with an even better storage oscilloscope, he was able to capture the source of the transient. It was the seemingly innocuous DC auxiliary relay on the same panel - a GE HFA six pole hinged armature auxiliary relay designed for use in interlocking circuits. There was no operating speed requirement as the most important design criterion was low battery drain. In some applications, the relay might remain energized for weeks or months. The manufacturer's catalog listed the 125 V coil as 2000 ohms (thus a low battery drain of 62.5 milliamps). The catalog included no information as to the coil's inductance. After all, it was just a simple auxiliary relay.

The transients were generated when a slowly opening external contact attempted to interrupt that 60+ milliamp current through the HFA relay's 25 henry operating coil. As the external contact energizing the relay slowly opens, the stored inductive energy in its 25 H operating coil raises the voltage across the contact until it arcs over and the DC current resumes. This scenario keeps repeating until the external contact has opened far enough so that the arcing stops. But now, the stored energy in that relay coil is released to charge the stray capacitance of the relay panel wiring connected to the positive terminal of the HFA coil.

Now the rise time was much faster (5 nanoseconds vs. 75 ns) to a peak of 4 kV (vs. 2.5 kV), and lasted longer (1 minute for each polarity versus 2 seconds). Even more troublesome was that some of the Zener diodes that had been used in relays as mini-transient suppressors of the oscillatory SWC test did not conduct fast enough to dissipate the energy in the fast transient voltage wave form, and partially punctured. This created a high resistance leakage path, and successive fast transients created more paths until the Zener failed thermally from excessive heat from the leakage current. This failure mode was difficult to diagnose, as the thermal failures occurred hours or days after the last fast transient.

The fast transient oscillatory SWC test was added to IEEE standard C37.90.1 in 1989. This 4 kV test voltage is required whether the installation is indoor or outdoor. Note IEC 602555-26 reduces the test level 50% for indoor installations. *(Taken from: '"Survival of the Fittest" – EMC in Electric Power Substations' by John T. Tengdin, P.E., OPUS Consulting Group, j.t.tengdin@ieee.org, Co-Chair, IEEE Power and Energy Society (PES) Working Group C2 (Substations), published in the IEEE Electromagnetic Compatibility Magazine – Volume 1 – Quarter 2, http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6244983.)*

749 **Pocket Wi-Fi hotspots paralyse Chinese metro lines**

Shenzhen Metro is blaming customer Wi-Fi for disruptions to its service. The subway system for the city of Shenzhen in Guangdong province, China, depends on the unlicensed 2.4GHz band to link up its signalling systems.

Following network failures in October, and a trial blocking of 3G signals earlier this month, the Shenzhen tube operating company wrote to China's regulator asking for permission to block the signal. Caijing magazine [1] reports that permission has now been refused, leaving Metro bosses at a loss on how to resolve the issue - which has seen two lines of the network repeatedly shut down and threatens other systems around China.

Customer Mi-Fi devices create Wi-Fi hotspots that are backhauled over China Mobile's 3G network, and they're very popular, particularly in Shenzhen - which, the South China Morning Post tells us, accounts for 80 per cent of sales [2]. That's the legit kit, which only nudges the 100mW legal cap, but engineers trying to keep the network running reckon black-market devices are kicking out three times that amount. They add that once eight of either kind come into range then the Metro's signalling system stops.

2.4GHz is reserved, globally, for unlicensed ISM (Industrial, Scientific and Medical) use, largely because it was considered worthless as it gets absorbed by water and because the band is rife with interference from microwave ovens. However, radio is a lot cleverer these days, and Wi-Fi is squeezing every cent out of the spectrum while Bluetooth dances around it, and numerous door locks, remote controls and other consumer devices fill any gaps which remain.

Originally it was the unlicensed nature of the band which made it so popular, but these days it is also the low cost of the kit. International standardisation means a Wi-Fi router, Bluetooth headset, or just a radio chip, can be sold anywhere - providing massive economies of scale.

There's also the freedom from regulatory process. Set up a link at 5.8GHz and (in the UK) you'll have to fill in forms and register each transmitter, but do the same thing at 2.4GHz and there's zero paperwork, making deployment quicker and cheaper.

The combination of these things drove Shenzhen Metro to connect up its signalling system at 2.4GHz, only to discover that it is now polluted with customer connections.

And Shenzhen is far from alone in its plight, as the same band is used by metro systems all over China, which will similarly fail once Mi-Fi devices become popular.

Blocking the 3G signal shuts down the devices, but it's hardly a sensible solution as it aggravates commuters. However, shifting to a licensed band will be expensive - both in terms of the equipment it will require and the frequencies in which it can operate.

Links: http://english.caijing.com.cn/2012-11-20/112296950.html; www.scmp.com/news/china/article/1084297/shenzhen-metro-shuts-3g-service-day-after-trains-inexplicably-stop

(Taken from "Pocket Wi-Fi hotspots paralyse Chinese metro lines. Using free band to run trains oddly didn't turn out well" By Bill Ray in The Register, http://www.theregister.co.uk/2012/11/21/wi_fi_knockout/?goback=%2Egde_3828357_member_188377735, also at: www.theregister.co.uk/2012/11/21/wi_fi_knockout/, and very kindly sent in by both Les McCormack and Chris Zombolas. Another link is: http://tinyurl.com/bwag996.)

750 High Power Microwave Missile Disables Computer Systems in Boeing Test

Aerospace company Boeing has successfully completed initial testing on a non-explosive missile that emits high powered microwaves to disable computer and electrical systems. The Counter-Electronics High-Power Advanced Missile Project (CHAMP) was tested at the Utah Test and Training Range by members of Boeing Phantom Works, the U.S. Air Force Research Laboratory and Raytheon Ktech.

In the initial test, CHAMP was fired at a two story building built on the test range and emitted a burst of high power microwaves that knocked out rows of personal computers and electrical systems inside the building. The television cameras set up to record the test were also disabled. CHAMP hit a total of seven targets with high power microwaves over a one-hour time period.

According to Keith Coleman, CHAMP program manager for Boeing Phantom Works, the successful completion of testing "marks a new era in modern-day warfare" where the technology may be used to disable the enemy's electronic and data systems before any troops or aircraft arrive. Boeing hopes that the project will change modern warfare by defeating electronic targets with little or no collateral damage.

(Taken from www.interferencetechnology.com/high-power-microwave-missile-disables-computer-systems-in-boeing-test/, 10/23/2012, for more info, visit: www.boeing.com/Features/2012/10/bds_champ_10_22_12.html)

751 Nine people killed in train collision, $12m damage, due to spurious (parasitic) oscillation

Abstract: On Monday, June 22, 2009, about 4:58 p.m., eastern daylight time, inbound Washington Metropolitan Area Transit Authority Metrorail train 112 struck the rear of stopped inbound Metrorail train 214. The accident occurred on aboveground track on the Metrorail Red Line near the Fort Totten station in Washington, D.C. The lead car of train 112 struck the rear car of train 214, causing the rear car of train 214 to telescope into the lead car of train 112, resulting in a loss of occupant survival space in the lead car of about 63 feet (about 84 percent of its total length). Nine people aboard train 112, including the train operator, were killed. Emergency response agencies reported transporting 52 people to local hospitals. Damage to train equipment was estimated to be $12 million.

Investigation Synopsis: The National Transportation Safety Board's investigation found that the Metrorail automatic train control system stopped detecting the presence of train 214 (the struck train), which caused train 214 to stop and also allowed speed commands to be transmitted to train 112 (the striking train) until the collision. This loss of detection occurred because parasitic oscillation in the General Railway Signal Company (GRS)/Alstom Signaling Inc. (Alstom) track circuit modules was creating a spurious signal that mimicked a valid track circuit signal, thus causing the track circuit to fail to detect the presence of train 214. The investigation found that the track circuit modules did not function safely as part of a fail-safe train control system because GRS/Alstom did not provide a maintenance plan that would detect anomalies in the track circuit signal, such as parasitic oscillation, over the modules' service life and prevent these anomalies from being

interpreted as valid track circuit signals. The investigation examined two near-collisions in 2005 near the Rosslyn Metrorail station that were the result of a loss of train detection. The track circuit in that case failed to detect the presence of stopped trains between the Foggy Bottom and Rosslyn stations. Tests on the circuit modules from the Rosslyn event conducted in 2009 as part of the Fort Totten investigation showed that the Rosslyn modules exhibited parasitic oscillation, and archived data showed that the Rosslyn track circuit had experienced this problem from as far back as 1988 (the earliest time from which data were available). In response to the Rosslyn event, WMATA developed, and issued technical bulletins requiring the use of an enhanced circuit verification test procedure. However, none of the WMATA technicians interviewed as part of this investigation was familiar with the enhanced procedure.

(Taken from: "Collision of Two Washington Metropolitan Area Transit Authority Metrorail Trains Near Fort Totten Station, Washington, D.C., June 22, 2009", Railroad Accident Report NTSB/RAR-10/02, National Transportation Safety Board, Washington, DC,. 2010, www.ntsb.gov/doclib/reports/2010/RAR1002.pdf.)

752 The costs of poor power quality, a CIGRE/CIRED report

Many professionals, including industry regulators, consultants, system and installation designers, maintenance managers, production managers, and financial managers, are concerned about the impact of the costs of poor power quality on businesses and how these costs can be managed.

Techniques for avoiding or reducing the impact of power quality issues are well known and the cost of their deployment relatively easily determined. However, assessing the potential cost impact of power quality (PQ) issues is difficult because, for example, the incidence of problems, the response of equipment, and the effect on process continuity are statistical in nature and are difficult to quantify. Although there have been numerous case studies, there has been, so far, no consensus on how the calculation or assessment of these costs should be approached.

This report provides a methodology for examining the economic framework for PQ. It will enable all interested parties to establish costs and benefits of PQ improvement and mitigation measures in a consistent and open manner.

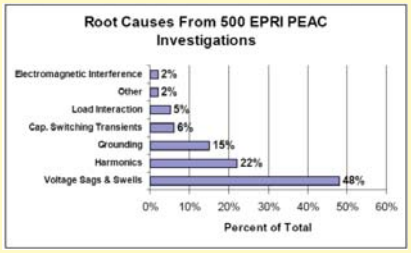
Studies in the USA

In year 1993, Clemmensen [46] provided the first-ever PQ cost estimate for U.S. manufacturing sector. The estimate derived that annual spending on industrial equipment due to PQ problems could sum up to $26 billion dollars for the U.S. manufacturing sector. It was estimated that for every manufacturing sales dollar, 1.5 to 3 U.S. cents (i.e., 1.5% - 3%) are spent to mitigate PQ problems.

A few years later in 1998, Swaminathan and Sen [46], in a Sandia National Laboratory report, estimated that U.S. annual power interruption cost reaches $150 billion. This estimate was based on a 1992 Duke Power outage cost survey in the U.S. that manipulated industrial electricity sales as the basis for the estimate.

Later in year 2001, EPRI's Consortium for Electric Infrastructure to Support a Digital Society (CIEDS) [47] produced a report based on a Primen survey in the United States. The report identified three sectors of the U.S. economy that are particularly sensitive to power disturbances:

- The Digital Economy (DE): telecommunications, data storage and retrieval services, biotechnology, electronics manufacturing, and the financial industry.
- Continuous Process Manufacturing (CPM): paper, chemicals, petroleum, rubber and plastic, stone, clay and glass, and primary metals.
- Fabrication and Essential Services (F&ES): all other manufacturing industries, plus utilities and transportation facilities.



Breakdown of the power quality found in more than 500 EPRI investigations

These three sectors collectively lose $45.7 billion a year due to outages and another $6.7 billion a year due to other PQ phenomena. It is estimated that the U.S. economy losses between $104 billion to $164 billion due to outages and another $15 billion to $24 billion due to PQ phenomena.

(Some extracts from the Introduction to "Economic Framework For Power Quality", CIGRE/CIRED Joint Working Group, C4.107, June 2011, ISBN: 978-2- 85873- 157-2, available from http://www.scribd.com/doc/71715649/467-Economic-Framework-for-Power-Quality. Also see "THE ECONOMICS OF POWER QUALITY – A SYSTEMATIC FRAMEWORK FOR THE ASSESSMENT", by José Luis Gutiérrez Iglesias, The Members of JWG C4.1071, and Alex McEachern, C I R E D 19th International Conference on Electricity Distribution Vienna, 21-24 May 2007, Paper 910, http://www.cired.be/CIRED07/pdfs/CIRED2007_0910_paper.pdf)

753 Earth's magnetic field reversal possible – knocking out satellites

Could we be witnessing the start of a reversal of Earth's geomagnetic field? That's the tentative suggestion from computer models created by Peter Olson and Renaud Deguen of John Hopkins University in Baltimore, Maryland (Nature Geoscience, DOI: 10.1038/ngeo1506). A reversal could expose us to solar winds capable of knocking out power grids.

(Taken from "Magnetic reversal?" in the "60 Seconds" column of New Scientist, 7 July 2012, page 7, www.newscientist.com. The geological record shows that the earth's magnetic field has reversed many times in the past, so it is expected to reverse again in the future. When it changes, it seems to change quite quickly, with a period of low or zero field inbetween. Many satellites would also be exposed to increased radiation, shortening their operational lives, in such a situation - Editor.)

754 Only 17.3% of LED lighting products sold in the EU complied with EMC Directive in 2011

Eighteen national market surveillance authorities (MSAs) involved in EMC ADCO participated in the campaign which was conducted between the 1st of January and the 30th of June 2011.

A hundred and sixty-eight (168) products were obtained and evaluated. Ninety one (91) LED lighting equipment products were of Chinese origin, whereas the origin of sixty-five (65) products could not be determined.

Technical compliance with harmonised standards

The notion of "compliance" is to be understood as compliance with an applicable harmonised standard.

The results of the technical compliance with the applicable harmonised standards showed large differences:

- Rather low compliance with the emissions limits: 61.5% of the tested, one hundred and sixty-six (166) products were found to be compliant
- There was a better level of compliance with the immunity limits: 91.5% of the tested, forty-six (46) products were found to be compliant.

Within this market surveillance campaign an additional study on harmonic current emissions (EN61000-3-2) was carried out. When applying the same harmonic limits as those for compact fluorescent lamps, one out of two samples, 46% of the assessed LED lighting equipment failed. This is clear evidence for the need of a prompt amendment of EN61000-3-2.

Administrative compliance

The overall administrative compliance was only 28.8% and, mainly regarded the CE marking and the Declaration of Conformity (DoC) requirements.

Almost 9% of the assessed LED lighting equipment did not carry the CE marking, whereas almost 24% were either not CE marked or did not carry a correct CE marking (format and size) as required.

Declarations of Conformity were available for 125 (74.4%) of the assessed LED lighting equipment with almost half of them having major deficiencies (e.g. missing reference to the Directive, incorrect Directive, identification of the product, incorrect standards, not issued by the manufacturer and/or authorised representative, etc.). Overall, for 67 (39.9%) of these products an acceptable Declaration of Conformity was presented.

General

In general, the level of compliance of the LED lighting equipment with the technical and administrative requirements was considered insufficient. Overall, only 29 (17.3%) of the products were in line with both technical and administrative requirements. The assessment of the technical documentation and of the immunity requirements were performed on an optional basis, the results of this assessment have not been taken in account in the overall level of compliance. This means that the overall level of compliance could be lower if both requirements had been assessed.

(Taken from "Final Report on the 4th Joint Cross-Border EMC market Surveillance Campaign (2011), LED Lighting Products" by the EMC Administrative Co-operation Working Group, which can be downloaded from http://ec.europa.eu/enterprise/sectors/electrical/files/emc/ms-campaign-fourth_en.pdf. Also of interest, are: www.youtube.com/watch?v=-FNIM-jXUPc and www.emcrules.com/2011/07/radio-interference-from-led-lighting.html. Dinex Lighting reckon that their LED lighting has Zero EMI emissions: www.ioonline.net/ioonlinetest/dinexlighting.aspx, presumably because their luminaires are simply strings of LEDs, requiring external power control that will create EMI emissions! The problem of emissions above 30MHz from modern lighting technologies was somewhat anticipated by: http://www.ofcom.org.uk/static/archive/ra/topics/research/topics/emc/8056cr2.pdf.)

755 Only 50% of consumer electronics sold in the EU complied with the EMC Directive in 2009/10

A total of 159 products were evaluated: 49 LCD televisions, 8 Plasma televisions, 39 Blu-Ray players and 63 DVD players. Overall technical compliance with the requirements of the harmonised standards was low at 50%. For emissions only, 72% were compliant and for immunity only, 69% were compliant. There were wide variations in the level of compliance between products.

Declarations of Conformity (DoC) were obtainable for only 81% of products. Of these, only 80 % were correct, with 15% containing major deficiencies.

Compliance rates differed widely between tested product categories, ranging between 20 and 56%.

Blue-ray players (available mainly from major companies) score significantly better than DVD-players (large low-cost segment) both in technical and administrative compliance.

However, there is no similar tendency in the case of Plasma/LCD TVs.

The generally poor results for DVD players and for the immunity of plasma TVs have substantially reduced the overall compliance of all tested categories to 34%.

Country of origin could not be determined for 11% of the samples.

(Taken from: "Report on the Joint Cross-Border EMC Market Surveillance Campaign 2009/10 on Consumer Entertainment Electronics Products", the 3rd EMC Market Surveillance Campaign by the EMC Administrative Co-operation Working Group, which can be downloaded from: http://ec.europa.eu/enterprise/sectors/electrical/files/emc/ms-campaign-third_en.pdf.)

756 EMC Crime

It is becoming common worldwide for criminals to jam wireless datacomms in factories, bringing production to a halt. They only stop jamming when paid to. (There was a paper on this at Hanover EMC this year.)

(Kindly sent in by Dipl.-Ing. Werner Grommes, on 14 June 2012)

Banana Skins

Banana Skins are kindly compiled for us by Keith Armstrong.

If you have any interesting contributions that you would like included please send them, together with the source of the information to: keith.armstrong@cherryclough.com

Although we use a rather light hearted approach to draw attention to the column this in no way is intended to trivialise the subject. Malfunctions due to incorrect EMC procedures could be life threatening.

John Woodgate's Column

Never a dull moment

About 360 new EMC standards documents have been circulated since last time, but many are not the stuff of which review articles are made. Nevertheless, there are enough hot topics to keep us amused.

CISPR meetings in Thailand

CISPR and its sub-committees met in November 2012. A very surprising document was submitted to CISPR/H committee by ITU. It includes a statement that emissions from unintentional radiators should be restricted to a level 20 dB below the receiver thermal noise. No mention of distance and no mention of any values of receiver thermal noise.

There seem to be few unresolved highly-controversial issues in CISPR at present. It could be a welcome lull, before issues related to the actual use of CISPR 32 and/or CISPR 35 by people not involved in their development arise.

Smart grid

We are still getting many long documents, some with pretty (and far too 'arty') graphics, but it is difficult to see that real progress is being made. No doubt the subject is large and complex, but it *should* emphasize practicalities.

Maintenance

The fact that standards need continual maintenance is often criticized, but if they were set in stone it would greatly inhibit the introduction of new, better and less costly techniques, which clearly should not be hampered. The following standards are some of those in the course of maintenance.

IEC 61000-3-3

The revision, to create Edition 3, attracted no negative votes at the CDV stage, so automatically goes forward to publication, with no FDIS voting stage.

IEC 61000-4-6

This revision has reached the CDV stage with significant doubt about some fundamental technical issues, which is most undesirable. National committees need to look more carefully at CDs, now that time-scales for the completion of products are being made ever shorter.

Although there were 23 pages of comments, several of a technical nature, the revision will proceed directly to publication with no FDIS vote because 29 countries out of 32 voted for it, including some that submitted numerous comments. This is surely a situation that creates considerable concern.

IEC 61000-4-30

This is at the CD stage and illustrates the point I make above; three important national committees have simply expressed 'support', but there are 34 pages of comments from ten other national committees. It does not seem likely that a large proportion of these comments are without foundation. A second CD has been produced.

IEC TS 61000-6-5

This is a Generic TS on immunity in power station and substation environments, and it has been decided to convert it to a standard. Planned changes include the deletion of switchgear (covered by IEC 62271) from the Scope and separation of the requirements for power stations from those for substations.

IEC 61000-6-1 and -2

These are the IEC Generic immunity standards, and enough National Committees support the need for maintenance for it to go ahead, but the response was surprisingly small (8 countries out of 38). It may be that few products are now assessed under the Generic standards because applicable product or product-family standards exist.

IEC TR 61000-2-5

This is about the classification of electromagnetic environments, and is of importance not only for 'regulatory' EMC (where products must cope with the environments in which they are intended to be used) but also for the far more difficult subject of EMC and functional safety, where the conventional concept of meeting prescribed immunity levels breaks down and must be replaced by risk assessment.

The EMC environment changes with time, maybe more dramatically than would be prudent. Power Line Communication (PLC) and the consequences of the Digital Dividend spring to mind. The proposed maintenance will more thoroughly address the power-frequency characteristics of environments, due to changes induced by PLC and embedded generation.

IEC 61000-4-11

This standard deals with voltage dips, short interruptions and voltage variations immunity tests. The responsible committee has put forward a number of proposals to simplify the standard and make its provision more representative of the real world. This initiative is welcomed and should be encouraged.

CISPR 11

It is intended to make a thorough revision of CISPR 11, and a simplification of the requirements for emissions above 1 GHz will be treated as a separate project.

CISPR 13, 20, 22 and 24

These are still being amended, out of necessity to cope with new developments, but CISPR has decided to withdraw CISPR 13 and 22 on 2017-03-05 (5 March 2017). This clear the way for CENELEC to agree to withdraw EN 55013 and EN 55022.

CISPR 15

The FID for the 8th edition has been delayed. Meanwhile, new proposed improvements are being lined up for future changes. Two Interpretation Sheets have been produced, and further work

is expected on emissions from LED lamps and associated equipment.

CISPR 32/EN 55032

Maintenance to create a second edition of CISPR 32 has begun, with the extremely optimistic schedule: CD: 2013-01 CDV: 2014-01 FDIS: 2015-01. The danger is that the quality of the text might be sacrificed in the quest for speed, so that there would be continual doubt about what the standard actually means. In addition, it seems that there is one CD, which in fact has already appeared, but five CDVs, which will be presented separately at the CDV stage and then combined. The CD describes clauses of the standard as 'sections'. More revision work is expected in 2013.

Other developments

Consistency of approach

CISPR is seeking to adopt clear guidelines, intended to improve consistency between standards, some of which have 'just grown' over many years without a sideways look at other standards. The proposed guidelines are 'motherhood and apple pie', so can hardly attract much negative comment, but the first draft has already been revised. The devil is likely to be in the detail, so until actual implementation is attempted, any potential difficulties may remain hidden.

CISPR D

A New Work proposal has been issued, on the measurement of emissions from vehicles, boats and internal combustion engines below 30 MHz. This refers to both magnetic and electric field emissions, but it is far from clear how reproducible results can be obtained for electric field emissions.

CISPR F Interpretation sheets

Two Interpretation Sheets are in process, one on retrofit extra-low voltage LED lamps and one on wall dimmers.

CISPR H

Although it was expected that this sub-committee would be disbanded because the Secretary had retired and no new candidate was forthcoming, at the last moment China and Korea offered candidates. It was decided to accept the offer from Korea.

CISPR I: VHF LISN

CISPR I has been looking at ways of improving the reproducibility of emission measurements, and has experimented with adding a LISN (Line Impedance Stabilizing Network) to each cable exiting the EUT (Equipment Under Test). This LISN has to work at frequencies above the range of the existing LISN specified in CISPR 16, so it called 'VHF (Very High Frequency) LISN. It may actually be required to work above 300 MHz, the upper limit of the VHF band.

This has resulted in a request to CISPR A to work on the specification, validation and application of the new device. The intention appears to be to apply it mainly to power cables.

EN TS 50217

This guide to *in situ* measurements of emissions is proposed for withdrawal as it is covered by CISPR 16-2-3/EN 55016-2-3.

IEC/EN 62488

This is a four-part standard for PLC for power system applications. Part 1 contains text on EMC matters that has not been reviewed by CENELEC, and this will be addressed. In IEC, the ACEC committee is responsible for EMC reviews, but there does not seem to be a 'running record' of which documents have been reviewed. The 62488 document was not reviewed in the period May - November 2012.

IEC TC77 Secretary

A new Secretary has been appointed. This may have interesting consequences, as the previous incumbent was very pro-active and was not averse to controversy.

IEC 61000-6-7 EMC and functional safety

A draft was circulated which evoked 39 pages of comments from national committees (I first wrote '39 ages...', which may be prophetic!). Comments include critiques of the basic approach – that specific limits can be set which ensure functional safety. A recent meeting of the committee made significant progress, partly due to an unusual attendance pattern, so this may be a temporary effect.

New Section of IEC 61000-4

It is proposed to produce a new Basic EMC standard 'Electromagnetic Compatibility (EMC) Part 4-XX: Testing and measurement techniques – radiated fields in close proximity - immunity test', applicable to the immunity of equipment to radiated electromagnetic energy coming from intentional radio-frequency (RF) transmitters, e.g. mobile phones, used in close proximity to other equipment. The frequency range covered is to be 9 kHz to 6 GHz.

The need to develop a basic standard is because this topic needs to be addressed as a horizontal standard by rather than in product standards, which would very likely differ undesirably.

Reconfirmation of IEC 61000-3-11

The maintenance committee has found no reason to update this standard and recommends reconfirmation, presumably for five years.

EMC classes A and B

The attempt by CISPR to clarify the definitions of these classes has failed because of established inconsistencies of use that preclude clarification. However, it seems to me that definitions that I have proposed in previous Columns could be used in future **without being applied retroactively**. At least, they could be a guide for newcomers to EMC.

Trend

It seems that the EMC scene is not getting simpler, as it appeared to be a few years ago, largely due to the rapid development of new technologies. So there should be ample material to review in the coming year.

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Know Your Standards

IEC 61000-3 series

As threatened last time, we continue our review with Part 3 of IEC 61000, whose Sections include two of the most important EMC standards, applying in Europe now and under active consideration (no doubt with many changes) in the Americas. Derived national standards apply in several other countries.

IEC TR61000-3-1

We start on a low note; in 1998 this was supposed to be a Technical Report giving an overview of the whole series. It was abandoned in 2011 after zero progress.

IEC 61000-3-2

This is one of the two controversial emission standards on 'low-frequency conducted disturbances', those known to their friends (and enemies) as 'mains harmonics'. It is a product-family standard, with a huge 'family', and applies to *everything* that has a household-type mains plug, or draws up to 16 A per phase. (OK, I know the risks of absolute statements - somewhere someone may make a product so abstruse that it would *never* be used on the public electricity supply, so doesn't have to meet this standard.)

It divides products into four classes, A to D, where Class A applies to most product types, Class B applies to mostly hand-held power tools, used for short periods only, Class C applies to 'lighting equipment', which has a complicated definition; it imposes strict limits because of the large proportion of the network load that is due to lighting, while Class D applies to computers and TV sets, which, unless they include mitigation measures, draw current from the mains supply as short pulses, whose low-odd-order harmonic currents are almost in the same phase for all products, so add arithmetically. The 3rd, 9th, 15th etc. add in the neutral wire of 3-phase and neutral distribution cables, and can cause severe overheating (theoretically the current can be 2.8 times the fundamental current). The 5th harmonic propagates into the Medium Voltage network, where it can excite resonance, which is very bad news for system overvoltage and reliability.

Classes A, B and D have each their own set of limits, but Class C doesn't; for some lighting products, the class A limits apply, for others, the class D limits and for yet others either a special set of limits or a 'special current waveform'. So there aren't unambiguous 'Class C limits' as such; one has to refer to 'table 1', 'table 2', 'table 3' or 'special waveform'.

The measurements involve quite a lot of data processing, so a special harmonic analyser is required, described in IEC 61000-4-7.

Current work on this standard includes a series of amendments to take new technology into account, notably LED lamps and new types of dimmers, which are new and controversial issues.

IEC 61000-3-3

This is the other 'terrible twin' of 'low-frequency conducted emissions', with 61000-3-2. It is a product-family standard applying to everything that can be connected to the public electricity supply and draws up to 16 A per phase. What it limits are voltage changes (reductions only), due to inrush current and load current fluctuations, especially repetitive fluctuations that can cause lighting to flicker. A special measuring system is required to evaluate this, the 'flickermeter' specified in IEC 61000-4-15.

IEC TR 61000-3-4

This deals with harmonic current emissions for products drawing more than 75 A per phase. It is advisory, because the connection of such products to the public supply always involves negotiation with the network operator. Before IEC 61000-3-12 was produced, it applied to products drawing more than 16 A per phase.

IEC TS 61000-3-5

This is a Technical Specification, of the type that is not intended to be converted to a standard. It deals with the same subject as 61000-3-3 but for products drawing more than 75 A per phase. The precise reason why it is a TS and not a TR is obscure, but, as for TRs, it cannot be notified under the EMC Directive in Europe.

IEC TR 61000-3-6

This Report is about harmonic emissions directly into the Medium Voltage (MV), High Voltage (HV) and Extra-High Voltage (EHV) networks. It is advisory because all such connections of loads are negotiated with the network operator.

IEC TR 61000-3-7

This Report complements IEC TR 61000-3-6, in dealing with voltage fluctuations due to loads on MV, HV and EHV systems. It is, of course, advisory.

IEC 61000-3-8

This standard specifies emission levels, frequency bands and disturbance levels for mains signalling ('ripple control'), which is mainly used by electricity suppliers, not in Britain but extensively elsewhere. There are three frequency bands defined for use in Europe - 3 kHz to 9 kHz, 9 kHz to 95 kHz and 95 kHz to 148.5 kHz. The upper band stops just short of the LF ('long wave') broadcast band in Europe. Controversy has recently arisen because some countries outside Europe want the bands extended to 500 kHz, because they do not have LF broadcasting. It isn't clear why different frequency ranges cannot be specified for different continents or ITU Regions.

IEC 61000-3-9

This was intended to be a standard for emission limits for interharmonics (currents at frequencies not related to the power frequency), but a controversial alternative approach has been

developed - measuring harmonic currents with a bandwidth equal to the power frequency, so that harmonics and any interharmonics are added together. This has been shown to result in equipment that does not cause any problem in practice nevertheless exceeding the limits. After a very long discussion over several years, a solution to this has appeared, which may be adopted during 2013. If so, IEC 61000-3-9 will be deleted from the programme of work of IEC SC77A.

IEC 61000-3-10

This was intended to be a standard for emissions in the frequency range from the 40th harmonic to 9 kHz, but no progress could be made over many years, due to changing technologies and lack of data on which to base realistic requirements. It is still in the programme of work, but no group is at present assigned to work on it.

IEC 61000-3-11

This standard complements IEC 61000-3-3 for products drawing more than 16 A but less than 75 A per phase, and for products drawing less than 16 A per phase which cannot meet IEC 61000-3-5.

IEC 61000-3-12

This standard complements IEC 61000-3-2 for products drawing more than 16 A but less than 75 A per phase. It takes a very different approach from that of IEC 61000-3-2, basing limits on the ratio of the load impedance to the supply impedance.

IEC TR 61000-3-13

This advisory Report is about emission limits for unbalanced loads connected to MV, HV and EHV systems.

IEC TR 61000-3-14

This Report concerns the assessment of emission limits for harmonics, interharmonics, voltage fluctuations and unbalance for loads connected to LV systems.

IEC TR 61000-3-15

This Report is about emission and immunity limits for dispersed generation systems - a complex matter. It was originally intended as standard, then as a TS and finally, considering that the technology is not yet mature, it remains a Report, *but perhaps not for ever.*

At present, there are no more Sections of Part 3, but there might be in future. Next time, we look at IEC 61000-5 series and perhaps the 61000-6 series as well.

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Vectawave sets up worldwide sales channels

Vectawave Technology Ltd has been designing and manufacturing power amplifiers for over 15 years. Until recently most of their production was distributed through third parties. In 2011/12 Vectawave invested heavily in a purpose built factory equipped with cutting edge design, build and test facilities and are now in a position to offer amplifiers directly to the market under the Vectawave brand.

Vectawave's core product is a range of air-cooled, Class A, broadband, RF power amplifiers for use in industrial, military and medical applications. The range, covering 10 kHz -6GHz with powers up to 2.5kW, is based on proven technology and the amplifiers are robust enough to meet the arduous conditions of EMC test applications. Hundreds are in daily use in EMC labs and test houses all over the world.

The company also manufactures a range of unique quadrature hybrids, couplers, directional bridges and low power amplifier modules to supply the requirements of system designers.

New sales channels have been established on every continent and local representatives can be found on the new Vectawave website:
www.vectawave.com/contactus
Tel: +44 (0)1983 821818
sales@vectawave.com
www.vectawave.com

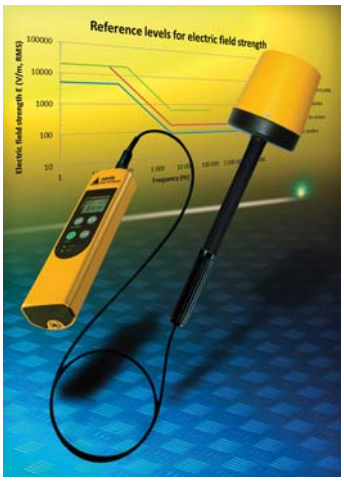
New RF radiation meter

The new NIM series RF radiation meter from **Link Microtek** has been specifically designed to enable plant managers and safety professionals to take quick and easy measurements of emissions from industrial sources such as RF heat sealers, RF induction heaters and semiconductor fabrication equipment.

Manufactured by Narda Safety Test Solutions, the NIM unit provides a straightforward means of ensuring compliance with the permissible exposure limits laid down in the ICNIRP international standard.

The battery-powered meter features an isotropic, dual-element probe that simultaneously measures electric and magnetic fields, both of which are required for equipment operating below 300MHz. Users can toggle between E-field and H-field readings at the press of a button, and the instrument features automatic zeroing at power-on and every 15 minutes.

The meter is available in two models: NIM-511 and NIM-513. The NIM-511 has a broad frequency range of 300kHz to 100MHz, making it suitable for virtually all equipment operating at ISM (industrial, scientific and medical) frequencies. The NIM-513 operates over the



narrower range of 10 to 42MHz, encompassing the ISM frequencies of 13.56MHz and 27.12MHz, which are widely used for semiconductor processing equipment, heat sealers and induction heaters.

With an LED-backlit 1.5in. LCD display, the meter will operate for about 22 hours on a charge of its NiMH batteries. It is supplied with a hard case, power supply and shoulder strap.

For further information, visit www.linkmicrotek.com and www.radhazonline.com.

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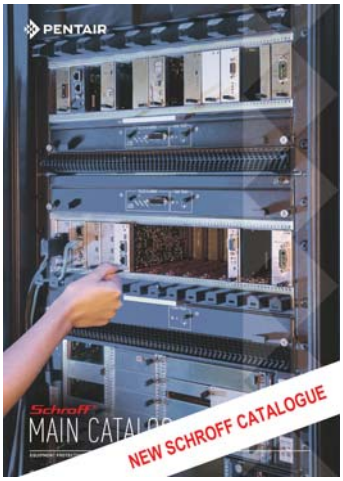
New 1200-page catalogue

Pentair Equipment Protection, the global business unit encompassing the Schroff, Hoffman and McLean brands, has brought out a comprehensive new catalogue detailing the entire range of **Schroff** products.

Over its 1200 pages, the catalogue presents key technical information on cabinets, cabinet accessories, cases, subracks, power supplies, cooling units, and systems and backplanes for a variety of bus technologies.

Several new products are featured, including a military-approved version of the Varistar cabinet, the minipac small case, a europacPRO subrack for industrial and harsh environments, and power supplies for MicroTCA and CompactPCI Serial systems.

For the first time, the catalogue also covers selected products from the Hoffman and McLean ranges, such as open-frame racks for datacom applications, outdoor cabinets for wall, pole or ground mounting, and both indoor and outdoor air conditioners for industrial systems. In addition, users will find comprehensive



service options and project examples for each product in the ServicePLUS pages.

This easy-to-use catalogue is clearly laid out in colour-coded sections and makes generous use of colour pictures, line diagrams and tables. It can be obtained by visiting **www.schroff.co.uk** and clicking on the Catalogue Request button.

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PRODUCT GALLERY

AR introduces new family of 400 MHz Solid-State RF Amplifiers

AR RF/Microwave Instrumentation has introduced a new family of solid-state RF amplifiers that instantaneously covers the 10 kHz - 400 MHz frequency range with both 200 watt and 400 watt models. The amplifiers are designed to deliver all the power required for applications using MIL-STD, DO 160, and other automotive standards. These models can be used independently or with AR's RF conducted immunity generators when specific tests require higher powers than our standard CI Systems can generate.

Model 200A400 and Model 400A400 (the 200 and 400 watt models, respectively) each utilize the highly linear devices in all high power stages to reduce distortion and improve stability. Each model is equipped with a Digital Control Panel (DCP), which provides both

local and remote control of the amplifier. The display provides operational presentation of Forward Power and Reflected Power plus control status and reports of internal amplifier status. Special features include a gain control, forward RF sample port, and a reflective RF sample port for precise power measurements.

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emcia Member

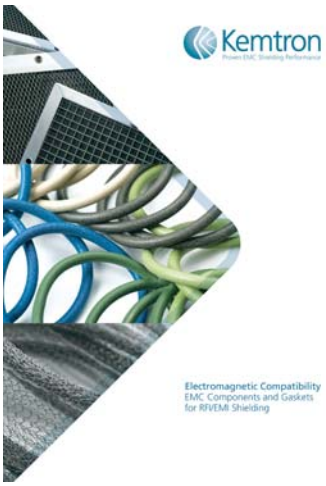
New comprehensive catalogue from Kemtron

Kemtron, the leading UK manufacturer of RFI/EMI shielding solutions, has published a comprehensive new catalogue in response to customer demand.

The 144 page printed catalogue has proved popular with customers who have limited Internet access, or who prefer the convenience of a paper version that they can bookmark, add notes or use as a working reference tool.

Managing director David Wall said, "We have had a fantastic response from customers in countries like Germany, India and Turkey, as well as the UK. They welcome the fact that they can have a printed catalogue when so many suppliers only offer information on the Web."

The catalogue provides detailed product overviews, technical specifications, application information and design considerations for Kemtron's range of RFI/EMI shielding solutions, as well as background information on EMC and useful design tools.



If information in the catalogue changes, Kemtron publishes updates on their website http://www.kemtron.co.uk/

Please contact Kemtron to order your free copy of the catalogue.

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Voltage Coefficient of Capacitance

By Matt Ellis, Syfer Technology and Tim Williams, Elmac Services

What capacitance do you get when you buy a multilayer ceramic capacitor? This might sound like an odd question, it is the value specified in the datasheet, surely. The actual answer is down to dielectric type, design and operational conditions, and there is a surprising degree of variation.

There are many factors which affect the actual capacitance value, some well documented, some less so. We all know about tolerance and temperature coefficient of capacitance, they are clearly defined in dielectric classification codes and part numbering systems. Where things become less clearly defined is for VCC or Voltage Coefficient of Capacitance.

	C0G/NP0			X8R	X7R			X5R
Dielectric characteristics	Ultra stable			Stable	Stable			Stable
IECQ-CECC	1B/CG	-	-	-	2C1	2R1	2X1	-
EIA	-	C0G/NP0	-	X8R	-	X7R	-	X5R
MIL	-	-	CG (BP)	-	BZ	-	BX	-
Rated temperature range	-55°C to +125°C			-55°C to +150°C	-55°C to +125°C			-55°C to +85°C
Maximum capacitance change over temperature range	0 ± 30 ppm/°C							
No DC voltage applied				± 15%	± 20%	± 15%	± 15%	± 15%
Rated DC voltage applied				-	+20 -30%	-	+15 -25%	-

Figure 1 Capacitance change versus temperature and voltage for common ceramic dielectrics

The effect of VCC

Dielectrics used in MLCC (MultiLayer Ceramic Capacitors) generally fall into two categories; stable and ultra-stable, or class II and class I. Class I are typically C0G or NP0; these are very stable with temperature and voltage so you get what you asked for, but with a relatively low permittivity, so you don't get as much capacitance-voltage product in a given volume as with other dielectrics. Class II are more variable and the lack of definition of VCC is where problems can occur.

VCC is a function of the properties of the dielectric material and the voltage stress applied, typically in volts per micron. The effect is negative and non-linear becoming asymptotic toward the limit of dielectric strength. In effect most of the loss occurs long before the part reaches its operational voltage limit, even with de-rating there will be significant capacitance loss. See fig.2.

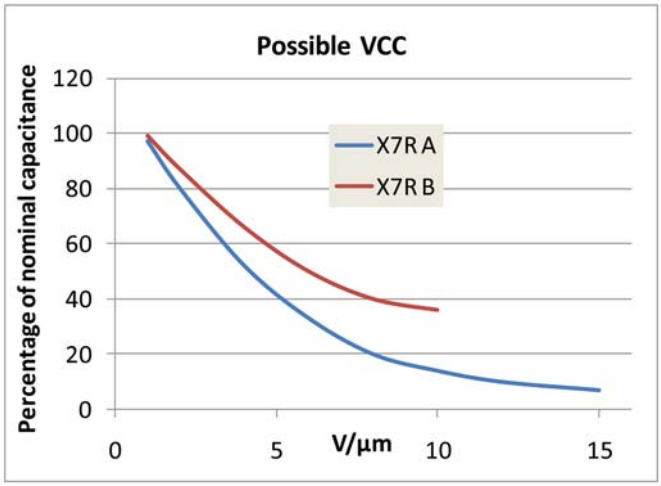


Figure 2 Capacitance change versus voltage stress across dielectric

Let's take EIA X7R for example, at "K" tolerance. The TCC (Temperature Coefficient of Capacitance) is ±15% over the specified temperature range, the tolerance is ±10% so running at the extremities of the specification we may face a variation from nominal capacitance of 23.5%. This will most likely be negative so if we assumed a nominal value of 100nF we now only have 76.5nF. But what about when we apply voltage? The VCC is not defined – look closely at Figure 1 and the EIA definition of X7R – and so there is no onus on the manufacturer to put this in the datasheet. We will assume that our part is 100V rated and we are going to use it at 80V. Using a relatively conservative design this will produce a voltage stress between the electrodes within the body of the component of 3.2V/µm which will result in a drop in capacitance of around 40% (see Figure 2), factor in the effect of temperature and the 10% tolerance and we could end up with only 40nF when we specified 100nF in the first place.

Bad as it sounds, this is by no means the worst it gets. With the pressures of price and size reduction manufactures of MLCCs

are forever reducing dielectric thickness; for end users voltage de-rating is becoming a thing of the past, particularly because there is always a desire to have the maximum capacitance in the smallest size. Greater than 90% loss of capacitance at rated voltage is not uncommon in the general market place. But this can be avoided for some parts by specifying 2C1 (BZ) or 2X1 (BX) dielectrics rather than standard commercial X7R (2R1). These options have a more tightly controlled VCC at the expense of absolute capacitance value in a given package (see Figure 1 again) – although, observe that a worst-case capacitance drop of 25-30% is still to be expected.

Safety issues

VCC is not just a problem with respect to circuit functionality; there can be legislative implications for certain equipment even if you fully understand VCC. EN 61010-1:2010 Safety requirements for electrical equipment for measurement, control, and laboratory use advises that for voltages up to 15kV equipment is considered hazardous live if it can discharge >45µC and ≥2mA. For above 15kV the same applies for energy levels >350mJ. If we consider a hypothetical high voltage laboratory power supply of 8kV with an accessible capacitive circuit then the 45µC rule restricts us to 5.6nF at 8kV (Figure 3). Let's assume the circuit in question requires a minimum of 2nF to function correctly; we know there will be some instability in the capacitor so we specify 5 x 3640 10kV 1nF parts. Unfortunately, the capacitors turn out to lose 75% of their value under 8kV so we end up with only 1.25nF. We can't just add more capacitors in parallel because it will push us over the 45µC limit; we could matrix parts in series and parallel to reduce the voltage stress and keep the nominal capacitance low but this will take up a lot of space and be costly. A more stable capacitor is required.

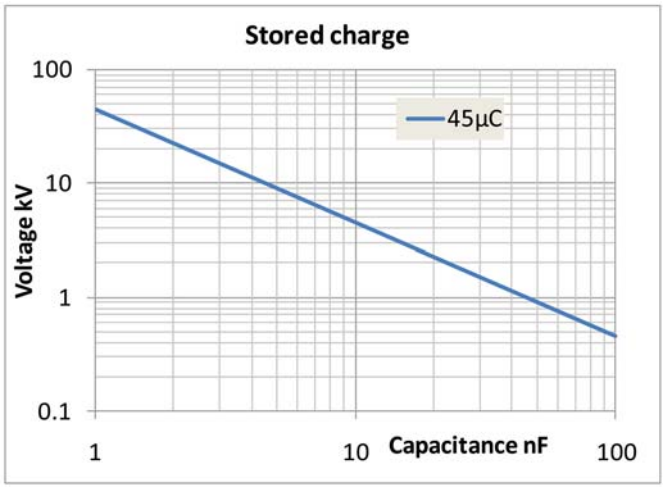


Figure 3 Stored charge of 45µC for voltage and capacitance

Luckily some X7R materials are more stable than others and, if requested, more suitable capacitors can be manufactured. Syfer can manufacture a 3640 1nF 10kV which will have less than 50% capacitance drop at 8kV; using this in the previous example would provide a residual capacitance at operational voltage of around 2.6nF as opposed to 1.25nF which would allow the circuit to function correctly and even allow for a reduction in component count from 5 to 4.

The effect on EMC design

What does this effect mean for EMC-related design issues? There are two principal widespread uses for MLCCs that are relevant to EMC: interface filtering, and decoupling. Whether a change in capacitance has a serious effect on either of these applications depends, more than anything, on frequency. This is because EMC applications cover a broad bandwidth, and the capacitor may be being used either above or below its self resonant frequency.

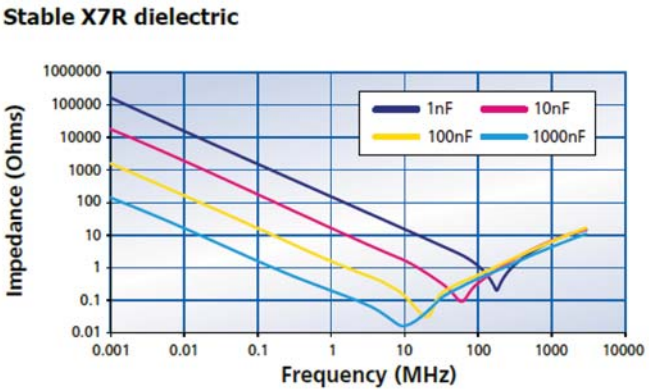


Figure 4 Self resonant frequencies for different capacitor values

Any two-terminal capacitor will show a minimum impedance at self resonance (Figure 4). This is given by $1/2\pi\sqrt{LC}$, where C is the actual capacitance and L is the combined inductance of the package and the vias, pads and tracks which connect to it. Above this frequency, it's not its capacitance value, but its self inductance, which determines the performance. Figure 4 shows the impedance of several values of capacitors. From this it's clear that for values above around 100nF and frequencies above 10MHz, the impedance (and hence loss of circuit effect) is rising with frequency, due to inductance.

Decoupling

Digital decoupling applications are normally most important in the VHF range and above, where clock harmonics on the power rails can cause high levels of emissions, or where incoming RF or transient interference can create undesirable disturbances. Decoupling local to each IC prevents this noise from circulating widely in the power distribution network, but practical components are acting as inductors in this region, so the actual capacitance value is less critical than the inductance. Package size and shape, and PCB layout, are the most important parameters; the capacitance must simply be large enough to keep the impedance at self resonance low.

A secondary reason (from the EMC perspective) for decoupling is to prevent significant voltage ripple on the power rails from exceeding the ICs' DC operating thresholds. This may require a minimum value of total capacitance in the system. Since it's usual for a decoupling regime to have many capacitors in parallel, it becomes a straightforward matter to calculate (e.g. using Figure 2 or similar data) by how much to increase the overall required capacitance, given a particular DC rail voltage and capacitor rating, to allow for the VCC.

Filtering

The situation with filter capacitors is somewhat different. Here, lower frequency applications are more typical. For both supply conducted emissions and conducted immunity the bottom frequency is 150kHz for commercial applications, and considerably lower for military and aerospace. In the kHz region, supply filtering is largely a matter of getting the maximum capacitance in the smallest space for a given voltage, with secondary issues such as leakage current and surge protection also being important. In signal line filtering, an additional aspect is that the capacitor should not affect the desired signal bandwidth, so there can be a critical trade-off between this limitation and the lowest effective filtering frequency.

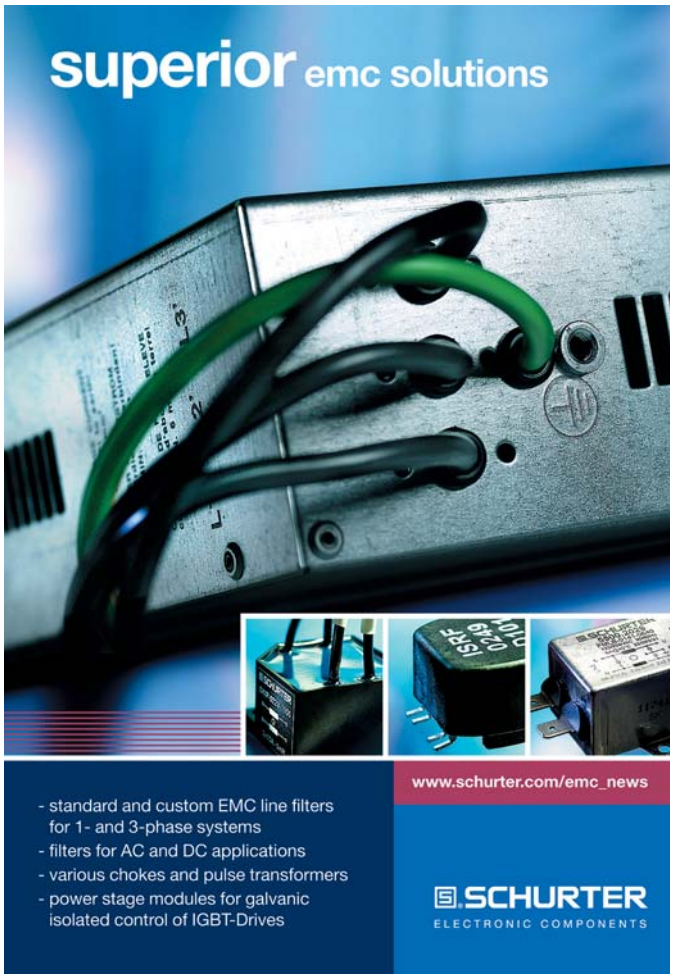
In either case there is real pressure on the MLCC characteristics, and it will be important to evaluate the effect of VCC on the filter's performance. A necessary consequence is that pre-compliance design EMC testing should be done with worst case DC voltages, low as well as high, present across the relevant components; or, a margin should be incorporated with respect to the LF emissions limits. For a single component filter, a 50% loss of capacitance will result in a degradation of attenuation of 6dB. For conducted immunity, over-testing by a factor of 2 – applying 20V rather than 10V, for instance – would be needed. One consequence of using a capacitor with a high VCC in an AC circuit, particularly (for instance) an X7R capacitor as an X- or Y-rated mains filter component, is that the filter attenuation will be modulated by the AC voltage. This effect, of course, would be hard to disentangle from other sources of 100/120Hz modulation in the power supply noise signature. Also, for multi-voltage DC supplies (such as 12/24V vehicle or marine applications) the VCC change could cause a filter to have substantially different characteristics at the different supply voltages – again, hard to separate from other causes of variation.

If your aim is only to control radiated emissions above 30MHz, by applying filter capacitors to cable interfaces, then the pressure is less since capacitance value is usually less critical; but as Figure 4 shows, capacitors in the range 1-10nF can expect to have self resonances in the range from 30 to 200MHz, which is the danger zone for cable coupling. It may well be that the self resonance is especially (and perhaps unexpectedly) effective at stopping a particular emission frequency, but then any variation in capacitance will shift this resonant frequency (by $\sqrt{\Delta C}$) with greater than expected results for the emission.

Conclusions

VCC is an important component characteristic which is often overlooked and can cause significant problems in certain applications. Voltage de-rating – running a capacitor significantly below its rated voltage – will limit the degree to which capacitance value degrades, but this generally involves a trade-off with package size. The same is true of choosing an ultra-stable dielectric such as C0G/NP0. Standard off the shelf components will vary in their performance so it is best to seek the advice of your supplier at the initial design stage to avoid the need for corrective action.

Matt Ellis is with Syfer Technology, Norwich; Tim Williams is with Elmac Services, Wareham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- filters for AC and DC applications
- various chokes and pulse transformers
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EMC design of high-frequency power "switchers" and "choppers"

The EMC benefits of LF mains isolating transformers, plus noise suppression for "floating" power networks and "floating" electronics

One of a number of "Stand Alone" articles on the EMC design of switch-mode and PWM power converters of all types

By Keith Armstrong, Cherry Clough Consultants Ltd, www.cherryclough.com

Issues 93-101 of The EMC Journal carried the preceding parts of this "Stand Alone" series – my attempt to cover the entire field including DC/DC and AC/DC converters, DC/AC and AC/AC inverters, from milliwatts (mW) to tens of Megawatts (MW), covering *all* power converter applications, including: consumer, household, commercial, computer, telecommunication, radiocommunication, aerospace, automotive, marine, medical, military, industrial, power generation and distribution, in products, systems or installations.

Hybrid & electric automobiles, electric propulsion/traction; "green power" (e.g. LED lighting); and power converters for solar (PV), wind, deep-ocean thermal, tidal, etc., are also covered.

Issues 93-95 used a different Figure numbering scheme from the rest, for which I apologise.

I generally won't repeat material I have already published, instead providing appropriate references to the EMC Journal [14] and my recently-published books based on those articles [15], so that you don't get bored by repetition.

7 Suppressing RF emissions from inputs and outputs

I began Section 7 in Issue 98 [72] and so far it has continued up to Issue 103 [108]. Despite my aim to only publish 'stand-alone' articles, each covering a single topic, the issue of suppression is so large that it is impossible to publish it all in a single issue. However, I have – mostly – succeeded in compartmentalising individual suppression topics in each article.

7.12 EMC benefits of AC mains (LF) isolating transformers

Where a power converter shares an AC mains power distribution network with other electronic equipment (which are probably fitted with mains filters) – a number of EMC issues arise that might be best dealt with by fitting the converter with a dedicated LF mains isolating transformer.

In earlier articles in this series I called mains transformers "Low Frequency (LF) transformers", to distinguish them from the High Frequency (HF) transformers that can be used to provide galvanic isolation at the switched or chopped outputs of power converters.

Nominal mains power frequencies range from 16 2/3Hz, through the more familiar 50Hz and 60Hz to the 400Hz generated by the electrical generators fitted to aircraft engines.

One of the main reasons for using switched-mode power conversion technologies is to achieve galvanic isolation for safety reasons with lower cost and weight, by replacing the large, heavy, costly LF isolating transformers used in traditional "linear" power converters with much smaller HF transformers. The EMC issues associated with HF isolating transformers were discussed in section 6 of this series, in [66].

However, LF isolating transformers can provide valuable benefits for EMC that are not available from HF isolating transformers. So although they are large, heavy and costly components (especially because of the high price of copper these days) they can sometimes be the lowest-cost EMC mitigation solution.

To help achieve cost-effectiveness in our EMC work (see [11], [12], and section 1.4 of [13]) we should therefore ensure that LF isolating transformers are considered early in the design process, along with all the other EMC design and mitigation issues. (Later in this Section I give an example of the many very costly incidents that have been caused by leaving EMC design issues to the end of a project.)

In section 7.3 in [72] (and later) I showed how a power converter's DM and CM noise currents were 'steered' by the capacitors and inductors in its input and output filters – and by their low-impedance bonding to the power converter's chassis/frame/enclosure/etc. which is designed to provide a low impedance over the frequency range to be controlled by the filters.

The result of this "noise current steering" is that they flow mostly in the power converter's assembly; with so little DM and CM noise current flowing outside of the converter that the limits for conducted noise emissions are met, and also to help comply with the limits for radiated noise emissions by reducing the noise that is radiated from any cables.

Where an AC mains power distribution network feeds two or more items of equipment spread over a site or vessel, the DM impedances of the phases can become different from each other due to unequal loading, and the CM impedance between the phases and the earth/ground – which is usually quite high (kΩ, possibly even MΩ) – can become quite low (10s of Ω, possibly even less) due to the stray capacitances of the long cables and the CM filters in other equipment.

Resonance effects in the mains power distribution can also cause unbalanced DM impedances between its phases, and the CM

impedances between phases and earth/ground can become very low indeed at resonant frequencies.

Such impedance characteristics associated with a mains power distribution network can degrade the performance of a power converter's mains filter (see [109]).

For example, when the CM impedance of the mains supply is low, the ratio between the impedance of the local noise loop (i.e. the one that is good for EMC) achieved by shunt capacitors in the mains filter, and the impedance of the external noise current loop in the mains supply (the loop that is bad for EMC) might not be as high as we would like. Figures 7.12-1 and 7.12-2 try to show this problem.

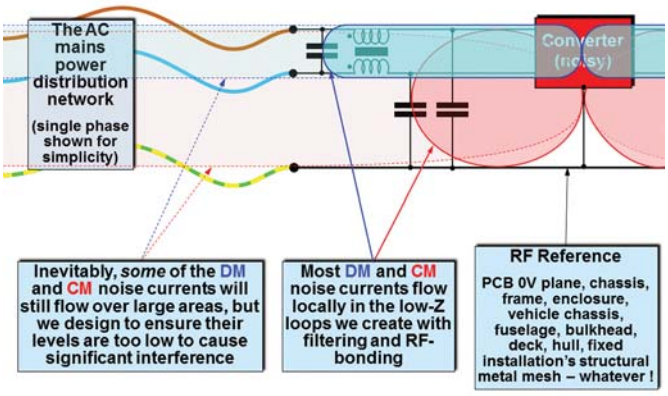

The AC mains power distribution network
(single phase shown for simplicity)
Converter (noisy)
Inevitably, some of the DM and CM noise currents will still flow over large areas, but we design to ensure their levels are too low to cause significant interference
Most DM and CM noise currents flow locally in the low-Z loops we create with filtering and RF-bonding
RF Reference
PCB 0V plane, chassis, frame, enclosure, vehicle chassis, fuselage, bulkhead, deck, hull, fixed installation's structural metal mesh – whatever !

Figure 7.12-1 The intended situation: mains filtering and RF-bonding provide low-Z local paths for noise generated by the power converter

Figure 7.12-1 is a copy of just the "mains side" of Figure 7.3-8 from [72], with a little more detail added to the AC mains supply to indicate a power distribution network. It tries to show how, by using a comprehensive mains filter (single stage filter shown, most practical filters will have two stages or more, see Figure 7.3-9 in [72]) we design so as to create small area, local, low-impedance paths for DM and CM noise currents across their whole frequency ranges.

Then, by Faraday's Law of Magnetic Induction (one of Maxwell's four famous equations) the noise currents will "prefer" to flow in the local loops we have created, rather than flow in the mains distribution network where they can cause conducted and radiated emissions problems.

(For more on this important EMC design technique, which works *with* the laws of nature rather than against them and so achieves the greatest cost-effectiveness, see [32], [33], [85] and [111]).

Figure 7.12-1 also shows how we like to use CM chokes in our mains filters to increase the apparent CM impedance of the AC mains power supply, to help to discourage CM noise currents emitted by the power converter from flowing in the mains supply network.

But we have a problem at lower frequencies, where CM chokes behave inductively rather than resistively (see Section 5.2.6 in [5]), because their inductance can series-resonate with the CM capacitance that naturally arises in the mains distribution network (the stray capacitance between mains cables and earth/ground structures).

Series-resonant current loops have very small impedances: just the resistance of their conductors. Because the CM capacitors in the mains filter have relatively high impedances at low frequencies, most of the CM noise current can end up flowing in part of the supply distribution network, possibly causing interference, instead of circulating locally as we want.

Also, if the mains filters fitted to other equipment connected to the same mains supply have capacitive CM inputs (instead of the inductive/resistive inputs provided by series CM chokes such as used in Figure 7.12-1), this extra capacitance can add to the distribution network cables' capacitances to create lower resonant frequencies.

So we can see that in real applications, mains filters can be significantly less effective at certain frequencies, than EMC laboratory tests would imply, and can even amplify noise emissions rather than suppress them! The result can be real-life interference problems, and these issues were all previously discussed in sections 7.3.3, 7.3.7, 7.3.12 and 7.3.13 of [84].

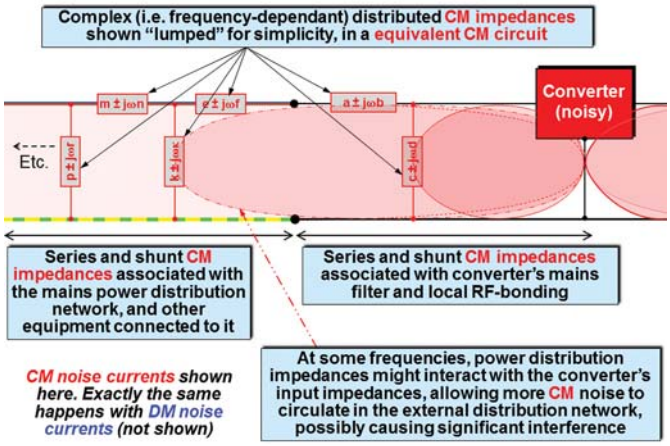

Complex (i.e. frequency-dependant) distributed CM impedances shown "lumped" for simplicity, in a equivalent CM circuit
Converter (noisy)
Etc.
Series and shunt CM impedances associated with the mains power distribution network, and other equipment connected to it
Series and shunt CM impedances associated with converter's mains filter and local RF-bonding
CM noise currents shown here. Exactly the same happens with DM noise currents (not shown)
At some frequencies, power distribution impedances might interact with the converter's input impedances, allowing more CM noise to circulate in the external distribution network, possibly causing significant interference

Figure 7.12-2 CM impedances in the power distribution can degrade mains filter CM attenuation at some frequencies

Figure 7.12-2 reduces the above discussion to a set of "lumped" complex impedances, trying to show that at certain frequencies the effects of the mains distribution (and other equipment connected to it), can cause mains filters to be less effective at certain, lower frequencies.

Fitting an LF isolating transformer, as shown in Figure 7.12-3, restores balance to three-phase DM impedances, which helps to keep mains harmonic emissions low and DM filters operating optimally (but note that Figure 7.12-3 only shows a single-phase system).

It also ensures that the power converter's external power supply has a high CM impedance from DC up to some low-ish frequency – perhaps several hundreds of kHz, even one or two MHz, for a low-kW-rated transformer, decreasing in frequency as the power rating increases – helping its mains filter to achieve its designed noise suppression whatever the impedance characteristics of the power distribution network over this frequency range.

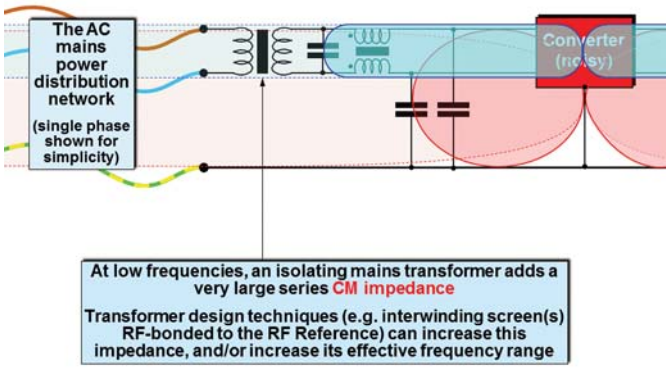

The AC mains power distribution network
(single phase shown for simplicity)
Converter (noisy)
At low frequencies, an isolating mains transformer adds a very large series CM impedance
Transformer design techniques (e.g. interwinding screen(s) RF-bonded to the RF Reference) can increase this impedance, and/or increase its effective frequency range

Figure 7.12-3 Using a mains isolating transformer

Because the main problem is that RF-suppressing CM chokes are predominantly inductive at low frequencies and so can series-resonate with the CM capacitances naturally present in the power distribution network and/or other equipment connected to it, there are three alternatives to fitting a large and costly transformer as discussed above:

a) Dampen the converter's mains filter
b) Increase the inductance of the power converter's input
c) Add line-ground capacitance to the network

Selecting mains filters so that they do not resonate when supplied or loaded with complex impedances in real life (as distinct from the resistive 50Ω impedances that are used in all EMC test laboratories for mains sources and loads), was covered in Sections 7.3.7 and 7.3.8 of [84], so I won't repeat that material here. When we are constructing our own mains filters, we need the damping information given in Chapters 5.2.8 and 5.2.9 of [5].

Items b) and c) in the above list both have the same aim, and may be applied individually or together: to reduce the resonance frequency of the distribution network so that it is much lower than the lowest noise frequency (f_{MIN}) emitted by the power converter, which is its lowest switching/chopping frequency.

There are two main concerns with manipulating the resonances caused by the interactions between the impedances in the power distribution network and those in the converter's mains input:

i. This type of approach is unsuitable where the configuration of the power network could change, unless so much line-ground capacitance or series inductance is added that in all possible configurations the series resonant frequencies are much lower than f_{MIN}.

ii. We should not try to be too clever by carefully tuning the series resonances to lie between two of the line spectra in the converter's noise emissions.

    Natural variability in the capacitance of the power distribution network and its connected equipment could cause this frequency to change over time and Murphy's Law tells us that it is bound to end up co-incident with a converter noise emission frequency – but only when it causes us the greatest possible trouble, cost and embarrassment.

Increasing the line-ground capacitance is a rather obvious thing to do, so I won't say any more about it here, other than to mention that the capacitors used should be appropriately Y-rated for safety reasons, and should cope with the ripple current from the AC supply and its harmonic and inter-harmonic waveform distortions (which can be up to 30% in some offshore platforms, see [54]) plus the noise voltages created by the emissions from electronic equipment – for the anticipated operational lifetime – despite their worst-case exposure to the physical and climatic environment (shock, vibration, humidity, temperature, etc.) and reasonably foreseeable lapses in maintenance.

If you think I'm being a bit alarmist about the importance of ensuring the high-reliability of capacitors fitted to a mains distribution network, please read [113]. This reference is to a case study of the catastrophic failure of power factor correction capacitors on board the Queen Mary, that left that vessel – with thousands of passengers and crew on board – in the pitch dark and without any electrical power, drifting entirely at the mercy of ocean tides, currents and winds, for about an hour.

We can increase the inductance of the power converter's mains input by adding series inductors commonly known as "line reactors", which are often used to decrease the mains harmonic emissions from power converters.

These series inductors were mentioned in Section 7.2 and shown on Figures 7.2-3 and 7.2-4 in [72], and will be discussed in more detail in the future section on suppressing mains harmonic emissions. In this situation they are used to reduce the frequencies of any resonance with network CM capacitances until they are so low that they are well below the lowest frequency emitted by the power converter and so do not influence its emissions.

But all series chokes reduce the mains power supply voltage to some degree, which can reduce the power available from the converter, can make it too inefficient (by wasting more heat) and also might cause an increased rate of undervoltage tripping due to sags or dips in the supply.

An alternative to large, heavy, costly high-power line reactors, is to fit a series inductor in the earth/ground connection to the power converter. This appears in series with the CM current and so has the desired effect of reducing CM resonant frequencies, but of course it does not have to carry the converter' electrical power so can be smaller, lighter and cost less.

Earth/ground inductors can only work when fitted in series with the one, single conductor connecting the power converter's chassis/frame/enclosure/etc. to the earth/ground structure of the site or vessel, as shown in Figure 7.12-4 (also see Figure 7.3.7 in [72]). In practice, it is easy for such installations to suffer from the accidental addition of earth/ground bonds over their operational lifetimes, defeating this inductor and potentially causing interference problems to suddenly start to occur for no obvious reason. Such installations need careful maintenance.

To ensure that there are no other earth/ground connections, some designs of power converters will need their chassis/frames/enclosures/etc. galvanically isolating from their support metalwork and other local metalwork, including the shields of

any cables connecting to them (causing problems for cable shielding effectiveness). Isolated power converter chassis/frames/enclosures/etc. should be made touchproof for safety reasons.

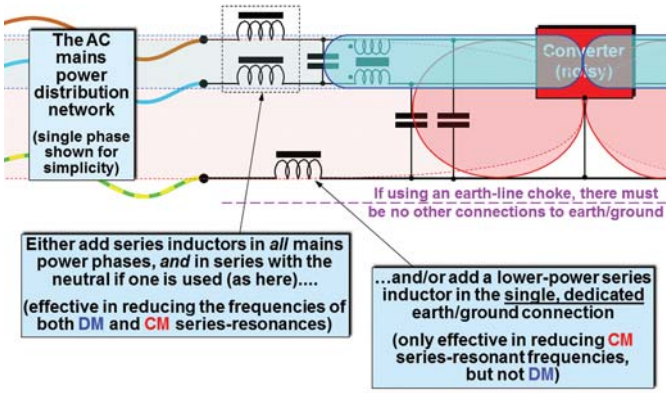

The AC mains power distribution network
(single phase shown for simplicity)
Converter (noisy)
If using an earth-line choke, there must be no other connections to earth/ground
Either add series inductors in all mains power phases, and in series with the neutral if one is used (as here)....
(effective in reducing the frequencies of both DM and CM series-resonances)
...and/or add a lower-power series inductor in the single, dedicated earth/ground connection
(only effective in reducing CM series-resonant frequencies, but not DM)

Figure 7.12-4 Using series inductors instead of a mains isolating transformer

Even where series inductors and/or shunt capacitors have been added to successfully reduce the series resonant frequencies to below the noise spectrum of the power converter without causing any of the problems mentioned above, we still have a resonant power network structure that will amplify any CM noises at its resonant frequencies.

Noises at these low resonant frequencies might exist in the mains distribution network, either emitted by larger power converters (due to their lower switching/chopping frequencies) or caused by lightning surges (most of the energy in a lightning stroke is contained in the spectrum below 10kHz) or surges caused by electrical faults.

Generally speaking, there is more energy available from continuous and transient noises on power distribution networks, at lower frequencies. So, tuning the network resonances to lower frequencies by increasing the series inductances at a converter's mains or earth/ground terminals might well reduce its noise emissions to the supply network, but could make the power converter more likely to suffer interference (even damage) due to the increased levels of noise and/or overvoltage surges at the network's resonant frequencies.

So, a less complicated solution, with far fewer unwanted side effects, is to use a large, costly mains isolating transformer dedicated to the power converter, and located immediately adjacent to it.

LF mains isolating transformers can use special design techniques (e.g. increased physical segregation of primary and secondary windings and/or adding one or more interwinding shields RF-bonded to the local RF Reference, etc.) to increase the frequency range over which they provide high CM impedance.

Remember, they only need to provide high CM impedance up to the frequency at which the RF CM chokes start to behave predominantly resistively (see Section 5.2.6 in [5]).

When using an isolating mains transformer, it may be possible to reduce the cost of the power converter's mains filter's CM filtering circuits, possibly even eliminating them entirely.

A mains isolating transformer might also prove to be sufficient on its own, without any mains filter at all, to prevent the CM noise from a power converter's mains input from circulating widely in the power distribution and exceeding limits or causing interference.

Of course, without an associated DM mains filter, an isolating transformer would do little (possibly nothing) for the power converter's DM noise emissions, or the resulting mains waveform distortion, but this is often not as much of a problem as the CM noise emissions anyway.

Where a power converter is fitted with a mains filter that deals with CM noise as well as DM, the majority of problems with widely-circulating CM currents occur at lower frequencies, below 150kHz. In this case experience seems to show that the normal type of construction for an isolating transformer is adequate for controlling CM currents in this frequency range.

A recent example of using a mains isolating transformer to fix a low frequency conducted emissions problem, was a new offshore gas drilling rig which cost US$ 500 million to build. It suffered from two separate EMC problems, one of which caused its large and powerful cranes to go out of control, causing very real safety hazards.

After four months without drilling and a great deal of lost production, a power quality expert was called in, who quickly fixed the safety problem by installing a 1MW isolating transformer. After both issues were resolved the manufacturers of the rig counted the real costs of the EMC problems, which exceeded US$ 54m.

Figure 7.12-5 shows the noise generated by the worst of the 700kW 3-phase drives fitted to its cranes, before and after fitting the 1MW isolating transformer to that crane drive.

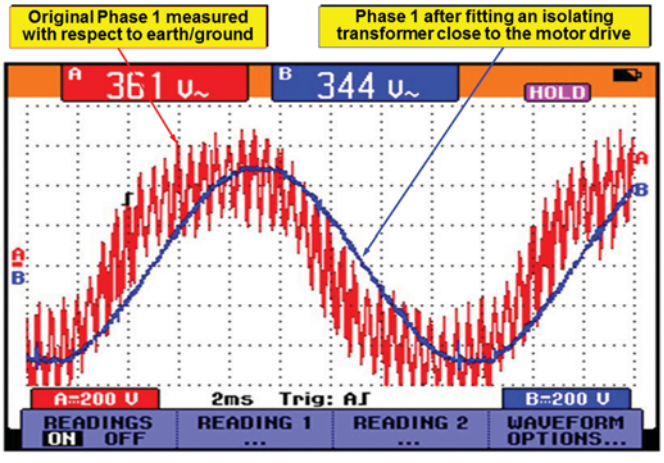


Figure 7-12-5 Example waveforms from a generator with a 700kW 3kHz AC motor drive load

Marine vessels and offshore platforms; aircraft; non-electric trains, and road vehicles all have the problem that their AC power supplies come from generators, which have between three and five times the source impedance of an onshore high-voltage-grid-connected transformer having the same power rating. So the non-linear currents that electronic equipment draws from mobile AC power supplies generally causes three to five times

the level of DM voltage disturbances that they would when powered from the AC mains power in a fixed installation on land.

But this problem was caused by CM currents from the crane's 700kW drive flowing in an uncontrolled manner all over the structure of the drilling rig, which had not been constructed to act as an RF Reference at such frequencies, resulting in the gross phase/neutral-earth/ground noise shown by the red trace on Figure 7.12-5 plus many problems with stray coupled noises on sensor and control cables due to the large noise voltages arising between different parts of the rig's structure, which caused the crane control gear to lose control – in turn causing major safety hazards that prevented the use of the rig.

The switching frequency of the crane's 700kW motor drive was 2kHz, as is the noise on the red trace of Figure 7.12-5. A spectrum analysis of the noise showed that it continued at significant levels up to about 2MHz, which is typical for unsuppressed high-power switch-mode power converters: 1000 times the switching rate.

Figures 7.12-6 and 7.12-7 are pictures of the transformer that was added, to give the blue waveform in Figure 7.12-5, and its installation.

Figure 7.12-6 The new 1MW isolating transformer that cured the CM waveform distortion

Figure 7.12-7 Another view of the new transformer, now in its weatherproof cabinet

The power quality expert complained that the drilling rig's manufacturer constrained him to use "quick-and-dirty" methods to remove the most obvious problems, rather than solve the problems at source (as he wanted to, and should have been done during the rig's original design and construction) by properly suppressing the power inputs and motor outputs of all of the crane motor drives.

He said that much of the rig is still suffering the full force of the CM voltage noise caused by the absence of mains filters on any of its variable-speed motor drives, including the 700kW drives for the cranes. (Figures 7.12-5 through 7.12-7 are only associated with one of the crane motor drives, the other motor drives associated with cranes, pumps, and other functions all still creating similar types of CM noise on the power distribution, but had not been seen to cause the safety problems with crane control that meant the rig could not be operated.)

The manufacturer of the rig had made many similar offshore drilling rigs beforehand, and never fitted any of their variable-speed motor drives with mains filters because, they said, "they were not needed" and so they saved their cost.

Well, like most such bad-EMC-engineering cost-cutting decisions, it only took one EMC problem to cost very much more than all the money that had ever been saved by deviating from good EMC design principles for the sake of reducing costs.

Quite possibly, the reason why they had crane control problems on this rig, when they hadn't seen any similar problems on previous rigs, was because of a change in the design of the electronic control equipment and/or silicon die shrinks for most/all of the integrated circuits (ICs) used on the printed circuits boards (PCBs) that resulted in them having lower noise margins.

This example of an EMC incident was previously reported in [110], which adds no more information to that given above.

Transformers aren't the only mains isolation technique, others that are commonly used include motor-generator sets and certain kinds of uninterruptible power supplies (UPSs), which can both reduce emissions of CM and DM noises into the mains power distribution networks. "M-G Sets" provide a very high degree of CM isolation between their input and output circuits due to their large physical separation, and with careful segregation of their input and output cabling and the equipment connected to them (and *their* cabling) could achieve high CM impedances to tens of MHz. They also provide a very high degree of DM isolation – something that a transformer cannot do.

To be effective in reducing DM and/or CM emissions, UPSs must be isolating continuous-on-line double-conversion types. UPSs are marketed using a wide variety of technical-sounding marketing terms, some of which are proprietary and most (all?) of which create the impression of much more technical capability than we actually get when we purchase them. So I have found that it is best to completely ignore all marketing hype and instead focus on the products' detailed technical descriptions.

Figure 7.12-8 shows a simple block diagram of the type of UPS that is needed to suppress DM and CM noise emissions to the mains network. It is important that it continually charges a

battery (or other electrical energy store, such as a supercapacitor) and – from that battery (or whatever) voltage synthesises the AC power to drive our converter.

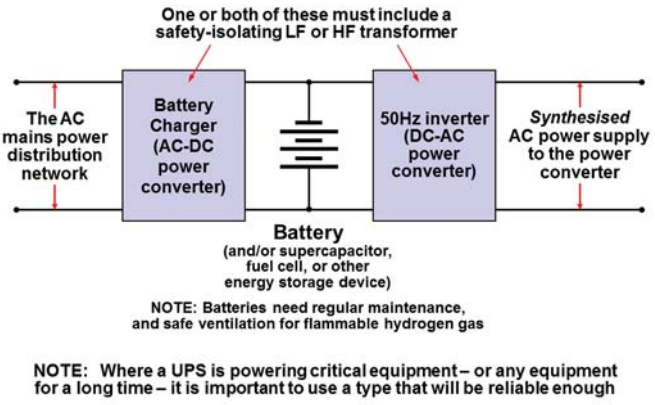

One or both of these must include a safety-isolating LF or HF transformer
The AC mains power distribution network
Battery Charger (AC-DC power converter)
50Hz inverter (DC-AC power converter)
Synthesised AC power supply to the power converter
Battery
(and/or supercapacitor, fuel cell, or other energy storage device)
NOTE: Batteries need regular maintenance, and safe ventilation for flammable hydrogen gas
NOTE: Where a UPS is powering critical equipment – or any equipment for a long time – it is important to use a type that will be reliable enough

Figure 7.12-8 Overview of a 'double-conversion continuous-conversion' UPS

The UPS's battery charger circuit, AC power generator circuit, or both, must contain an LF or HF isolating transformer. Like the LF isolating transformers discussed earlier, and the HF isolating transformers discussed in Section 4 in [64], their effectiveness for suppressing CM emissions depends on their design and construction, with special high-frequency high-isolation techniques being available (often at extra cost).

DM suppression is achieved by passing all the power via the battery (or other energy store). Like the DC Link suppression capacitors discussed in Section 7.6 in [99], the lower their shunt impedance at the frequencies of interest, the better their DM noise suppression. It may be necessary to parallel a number of different technologies, for e.g. batteries, supercapacitors and high-value metallised film capacitors, to achieve the required DM suppression across the whole frequency range of converter noise.

Continuous-on-line double conversion isolating UPSs are generally effective at low frequencies (say, up to 100kHz) but models with higher-frequency specifications are available, and I have seen some UPS products that specified no less than 80dB attenuation for both DM and CM noise at all frequencies from DC to 1GHz! Obviously, we pay extra for such specifications, and most "commodity" UPSs do not even include noise attenuation specifications in their data sheets, so we should always assume such performance to be quite poor until we have seen independent evidence that proves otherwise.

It is important to beware that some M-G Sets and UPS's generate so much noise they make EMC worse overall, or create poor power quality (e.g. by emitting excessive harmonic or inter-harmonic waveform distortions), or are too unreliable.

Someone who worked at a '24/7/365' continuous-steel-strip-production mill once told me that after losing costly production due to mains interruptions and outages, they installed *very* large, powerful and costly high-power UPSs to power their *entire* production line, only to find that the UPSs were less reliable than the raw mains supply they had been using!

We must remember to always ask for trustable evidential proof of any/every specification or feature that we need from anything that we purchase, and never make assumptions no matter which supplier we deal with.

7.13 Noise suppression with "floating" power networks or "floating" electronics

7.13.1 Converters powered from floating AC power networks (insulated neutrals)

Ships and other vessels generally use mains supplies that do not have the neutral of their mains power supply directly bonded to their earth/ground structure (see [60]), and some land-based installations also use this practice. This is known as an IT power network (nothing to do with Information Technology!), and is often described as a "floating" mains supply.

It is a common mistake (that even appears in some standards, for example EN/IEC 61800-3) to assume that mains filters require a connection to an earth/ground, and so cannot be used with floating mains power networks.

(A safety technique used with earthed/grounded mains power network is that they open fuses or circuit breakers to remove electrical power from a circuit that has suffered from an insulation fault. However, in some especially aggressive environments – such as marine – insulation faults are quite common and the power networks would fail too often. When controlling a vessel like a ship, an interruption in the power that impairs the control can cause huge safety risks (e.g. running onto rocks). So they use floating mains power networks fitted with sensors to measure the (normally high) impedance between each phase or neutral and the earth/ground of the vessel or site, to determine when insulation failures have occurred and be able to fix them before another one happens. Mains filters have leakage currents in their "earth/ground labelled" terminals, which would prevent the insulation-failure detectors from working correctly.)

The common mistake goes on to say that in such situations the only mitigation possible is to ensure that all the other equipment on the site is immune enough to the noise suffered by the power distribution system (which is easier said than done if they can't use mains filters).

This mistaken approach ignores the possibility of interference with other equipment (on other vessels or off-site) and with radio receivers used anywhere, so is far from being any kind of real EMC solution.

Anyway, as the offshore drilling rig example above showed (see Figures 7.12-5, 6 and 7), it can be very difficult to predict whether unfiltered power converter noise emissions will cause interference problems with the rest of the system until everything is installed and operating. By which time, of course, any fixes will be time-consuming and very costly indeed.

The common mistake, of course, is to confuse the RF Reference terminal of a mains filter with the earth/ground electrode that is stuck a few metres into the soil, or the metal hull of a vessel that provides the exact same function by being in direct large-area contact with a body of water lying on the surface of our planet (e.g. lakes, rivers, seas).

It isn't helped by the fact that most (if not all) mains filters (and many other types too) incorrectly identify their RF Reference terminal with the IEC symbol for earth/ground, and sometimes actually label it as Earth or Ground! And most data sheets, application notes, articles, guides and books describe the RF Reference terminal of a mains filter as its Earth or Ground terminal.

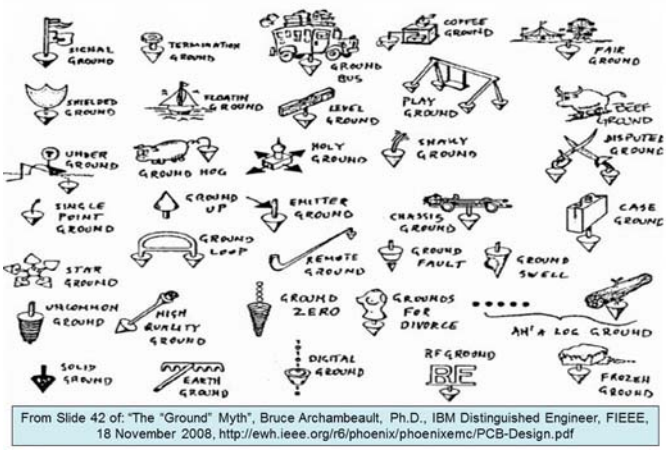
This isn't the only situation in which the confused jargon associated with the terms Earth or Ground in circuit and EMC design has caused costly mistakes – which is why in all my articles, training courses, guidebooks and textbooks I always strongly recommend *never using the terms Earth or Ground for anything that is not actually an earth/ground electrode* (metal rod stuck in the soil) or its marine equivalent (metal hull or structure of a vessel such as a ship or drilling rig, oil/gas production platform, etc., that is in direct large-area contact with a river, lake or sea).

All of the conductors and conductive structures that are connected together, and usually (but not always) connected to actual earth/ground electrodes for safety reasons, should be called electrical Bonding Networks, or BNs; or electrical Common Bonding Networks, or CBNs (as per the terminology in IEC 61000-5-2, which is concerned with good practices in cabling and earthing/grounding).

No electronic DC power rails, such as "zero volt" rails (0Vs) should ever be called earth or ground rails, and nothing should ever be said to be at earth or ground potential.

No circuit diagrams should ever use the words Earth or Ground, or their related symbols (unless they *really do mean* an actual metal rod that is stuck a few metres into the soil, or the marine equivalent.

Serious problems caused by the confusion arising from the jargon use of the words Earth or Ground have been well-known for decades, especially in system, circuit and EMC design. Figure 7.13-1 is copied from slide 42 of [112], and I have seen its creator, Dr Bruce Archambeault of IBM, use it many times in similar presentations and articles in earlier years.



From Slide 42 of: "The "Ground" Myth", Bruce Archambeault, Ph.D., IBM Distinguished Engineer, FIEEE, 18 November 2008, http://ewh.ieee.org/r6/phoenix/phoenixemc/PCB-Design.pdf

Figure 7.13-1 Some of the many types of symbols for different grounds (humorous!)

Regular readers of this series might remember Figure 7.2-4 in Section 7.2 of [72], where I first introduced the concept of "noise current diversion by working with the laws of Physics", which make noise currents "prefer" to flow in the loops with the lowest overall impedances, that cause the least emissions. Well, I have duplicated Figure 7.2-4 as Figure 7.13-2 so that you don't have to look it up.

Figure 7.13-2 shows the typical way we use input and output filters and RF-bond local metal structures to use them as RF References, to help divert noise currents generated in the power converter's devices so that they "prefer" to flow in small, low-Z, local loops and not in the mains power distribution network.

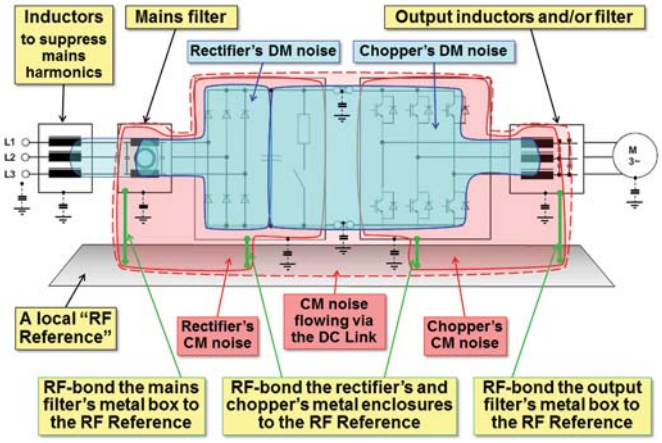

Inductors to suppress mains harmonics
Mains filter
Output inductors and/or filter
Rectifier's DM noise
Chopper's DM noise
A local "RF Reference"
Rectifier's CM noise
CM noise flowing via the DC Link
Chopper's CM noise
RF-bond the mains filter's metal box to the RF Reference
RF-bond the rectifier's and chopper's metal enclosures to the RF Reference
RF-bond the output filter's metal box to the RF Reference

Figure 7.13-2 Example VSD fitted with filters and RF-bonded to an RF Reference

These two figures (7.2-4 and 7.13-2) use the local metal structures as the RF Reference simply for reasons of saving cost by using existing metal structures for EMC purposes.

Converters that contain their input filters, LF rectifiers, DC Links, output switchers/choppers (and any LF or HF isolation transformers, HF rectifiers, output filters, etc.) within a single metal enclosure, use that enclosure (or an internal chassis or frame) as their RF Reference and have no need for an external RF Reference.

If you remembered Figure 7.2-4 without me having to tell you, you might also remember that the figure that preceded it was (of course) Figure 7.2-3, which I have duplicated in this article as Figure 7.13-3.

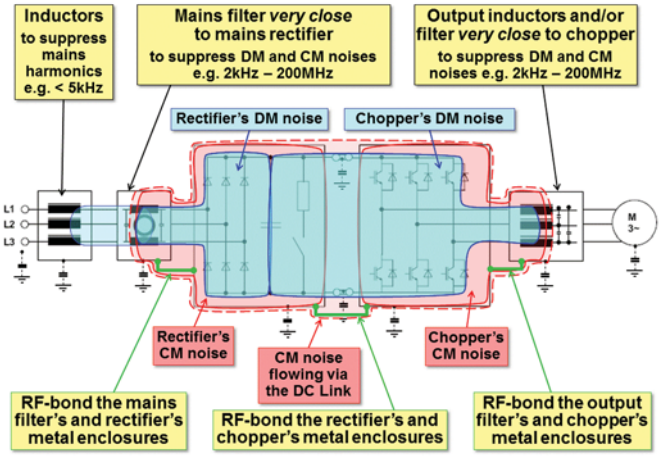

Inductors to suppress mains harmonics e.g. < 5kHz
Mains filter very close to mains rectifier to suppress DM and CM noises e.g. 2kHz – 200MHz
Output inductors and/or filter very close to chopper to suppress DM and CM noises e.g. 2kHz – 200MHz
Rectifier's DM noise
Chopper's DM noise
Rectifier's CM noise
CM noise flowing via the DC Link
Chopper's CM noise
RF-bond the mains filter's and rectifier's metal enclosures
RF-bond the rectifier's and chopper's metal enclosures
RF-bond the output filter's and chopper's metal enclosures

Figure 7.13-3 Example VSD fitted with filters and RF-bonded together

Notice that Figure 7.13-3 shows no connections to earth or

ground, because earth or ground electrodes (rods stuck in soil, etc.) have *no relevance at all* for the noise emissions generated by any electronic devices, such as the power converters that are the subject of this series.

So, there are no EMC problems at all in using mains filters on power converters that are powered by "floating" mains power distribution networks.

However, there can be some practical issues that need to be taken into account. Because the filters fitted to the inputs and/or outputs of power converters must be RF-bonded to the converters' metalwork (usually their chassis, frames or enclosures), using them as RF References to provide small, low-Z current paths – when using floating mains supplies, this metalwork must not connect directly to the earthed/grounded structure of the vessels or sites.

This is so that the filters' leakage currents will not flow into the earth/ground structures and compromise the correct operation of the insulation failure detection systems on the floating mains power distributions.

So, for safety reasons, the floating converter metalwork that the mains filters are RF-bonded to must be made touchproof to prevent personnel from suffering electric shocks. This can add extra design complexity and cost, but it is certainly a much preferable solution than trying to use power converters and other electronic equipment without any mains filters at all!

Figure 7.13-4 provides a simpler view of the arrangement of the filtered floating power converter sketched in Figure 7.13-3.

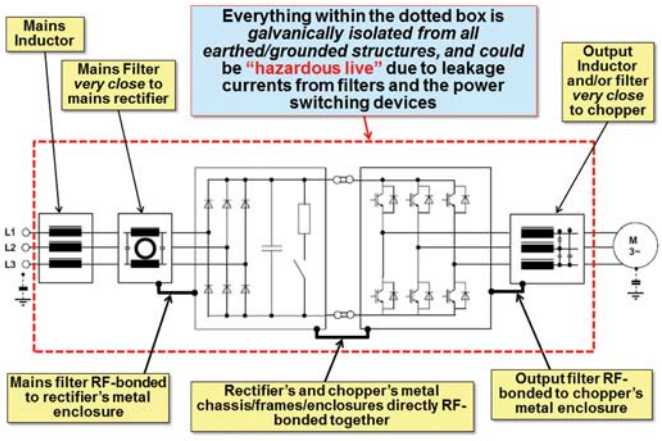

Mains Inductor
Mains Filter very close to mains rectifier
Everything within the dotted box is galvanically isolated from all earthed/grounded structures, and could be "hazardous live" due to leakage currents from filters and the power switching devices
Output Inductor and/or filter very close to chopper
L1
L2
L3
M 3~
Mains filter RF-bonded to rectifier's metal enclosure
Rectifier's and chopper's metal chassis/frames/enclosures directly RF-bonded together
Output filter RF-bonded to chopper's metal enclosure

Figure 7.13-4 A simpler view of the floating power converter technique

When using floating power distributions and floating power converters, higher-frequency noise emissions can be a little more difficult to control than when everything is directly bonded to the earthed/grounded metal support structures.

These high-frequency noise emissions can often be usefully reduced by connecting one or more low-value capacitors from the floating RF Reference that has been created (see Figure 7.13-3) to the local metal support structure (which is usually earthed/grounded) as shown in Figure 7.13-5.

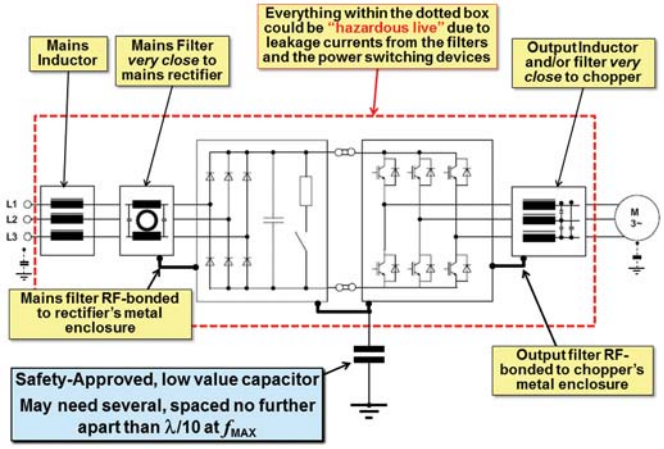

Everything within the dotted box could be "hazardous live" due to leakage currents from the filters and the power switching devices
Mains Inductor
Mains Filter very close to mains rectifier
Output Inductor and/or filter very close to chopper
L1
L2
L3
M 3~
Mains filter RF-bonded to rectifier's metal enclosure
Output filter RF-bonded to chopper's metal enclosure
Safety-Approved, low value capacitor
May need several, spaced no further apart than λ/10 at f_{MAX}

Figure 7.13-5 Indirectly RF-bonding a floating power converter to its local earth/ground

Because it only has to provide a low-Z path for higher-frequency noise currents, the capacitor values can be reduced so that they do not compromise the correct operation of the insulation failure detection systems, whilst still providing useful RF noise suppression.

For more detail on suppressing floating power converters with indirect RF-bonding capacitors, see Section 7.13.2 below – bearing in mind that this section is not concerned with floating AC supplies with their insulation failure detection systems.

When using cable shields/armour instead of output filters (as discussed in Section 7.5 in [92]), capacitive RF-bonding could be used for the output cable's shield/armour, fitted either at the power converter's output or the load's (e.g. a motor) terminal box, or both.

Capacitive shield/armour RF-bonding will not be as effective as a proper 360° shield-bonding (described in full detail in Section 4.6 in [5]), but may be good enough if the lead lengths of their RF-bonds are kept very short. Such shield/armour-bonding capacitors should be safety-approved and rated for the full phase-to-phase voltage, and the values of the capacitor(s) used where a floating converter drives an earthed/grounded load (such as a motor) may have to be a compromise between the value needed to control the *lowest* noise frequency to be controlled (f_{MIN}), and the value above which the leakage current is considered excessive by the relevant safety standards, or which compromises the operation of the insulation failure detection circuits on the floating power distribution.

This is pretty much the same set of design compromises as when adding noise suppression capacitors as sketched in Figure 7.13-5. It is of course very important indeed to always ensure that all relevant safety standards are fully complied with, and that the product, system or installation will be safe over its anticipated lifecycle.

There is a way to completely eliminate the safety and construction problems of having to float power converters and their filters when using floating mains supplies, as well as avoiding the compromises and non-idealities of capacitive cable shield RF-bonding: fit the converter with an isolating LF mains transformer, as discussed in Section 7.12 above.

With a co-located LF isolating transformer in series with the power converter's mains input, the converter's chassis/frame/enclosure/etc. and all of its associated filters and cable shields/armour can be directly RF-bonded to the local earth/ground metal structure (and use it as an RF Reference), without compromising the floating mains distribution in any way (except for the small CM leakage current from primary winding to secondary and the transformer's enclosure, which can be reduced by appropriate transformer design techniques if necessary.

This is the same scheme that is sketched in Figure 7.12-3, and is also merely Figure 7.13-2 with an isolating transformer attached in series with its mains input.

Where a power converter is connected to a high-voltage power distribution network, with its own dedicated, co-located step-down isolating mains transformer, our work is already done! The HV distribution network is floating, and on the other side of the step-down transformer the power converter and its filters and any shielded cables can be directly RF-bonded to the local earth/ground structure and use it as an RF Reference as discussed above and shown in Figure 7.12-3.

Sorry, but I feel the need for a little tirade on earthing/grounding jargon, before I can leave the issue of filtering converters that are run from floating supplies.

Looking again at Figure 7.13-3, we see that it shows stray capacitances to the earth/ground, but no actual connections. No electromagnetic noises generated by the electrical activities in electronic circuits have ever been reduced or eliminated by connecting them to an earth/ground electrode. The earth/ground is not a "sink" for noise, and it never has been and never can be. The concept of diverting noise currents so that they are absorbed in the earth/ground is simply a misunderstanding and a myth.

Anyone who ever "got rid" of noise by "earthing/grounding it" had actually improved the local RF Bonding and allowed noise currents to flow in lower-impedance, more local loops that caused less interference. But because of confusion caused by the use of jargon terminology, the EMC benefits were mistakenly thought to have somehow had something to do with the earth/ground electrode stuck in the soil acting as a sink of some kind, which is actually impossible in this universe.

Ah, I feel better now, and can get on with the rest of this little article.

7.13.2 Isolated converters powered from DC power networks

Isolated DC-powered electronics are typical of many automotive, marine and aircraft applications, where the chassis/hull/fuselage/etc. of the vehicle is used as the battery return conductor (a very bad EMC practice which dates from pre-electronic times but seems impossible to get away from).

The DC supply is connected to the chassis/hull/fuselage/etc., but the RF References of electronic units cannot be directly connected to them in case bad connections between metal parts allows large battery currents to flow through the electronics, probably causing damage or even a fire.

The solution that allows the return current paths to flow with the smallest loop areas, which is the best for EMC, is to RF-bond the electronics' RF Reference (e.g. its metal chassis/frame/enclosure, PCB 0V plane, etc.) to the vehicle's chassis/hull/fuselage/etc., using capacitors and their connections that achieve low-enough impedances at the lowest frequency to be controlled (i.e. at f_{MIN}), and also at the highest frequency to be controlled (i.e. at f_{MAX}), as sketched in Figure 7.13-6.

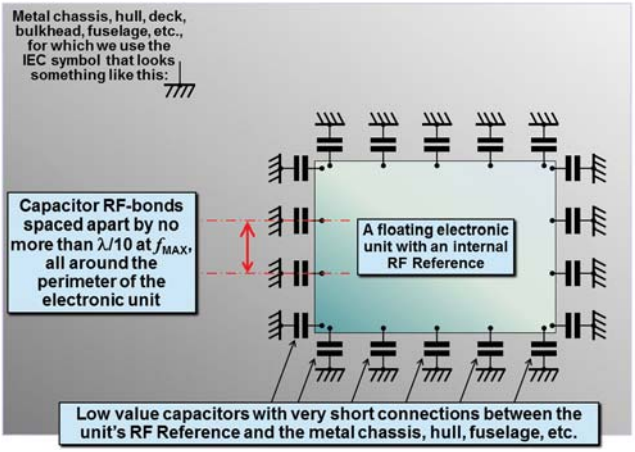

Metal chassis, hull, deck, bulkhead, fuselage, etc., for which we use the IEC symbol that looks something like this:
Capacitor RF-bonds spaced apart by no more than λ/10 at f_{MAX}, all around the perimeter of the electronic unit
A floating electronic unit with an internal RF Reference
Low value capacitors with very short connections between the unit's RF Reference and the metal chassis, hull, fuselage, etc.

Figure 7.13-6 Capacitive RF bonding for isolated electronics powered from a non-isolated DC power network

These capacitors should be spaced no further apart than λ/10 at the highest frequency to be controlled (f_{MAX}). Another way of stating this is: $\leq 30/f_{MAX}$, in air, with f_{MAX} in MHz giving the maximum spacing in metres, whereas f_{MAX} in GHz gives the spacing in millimetres.

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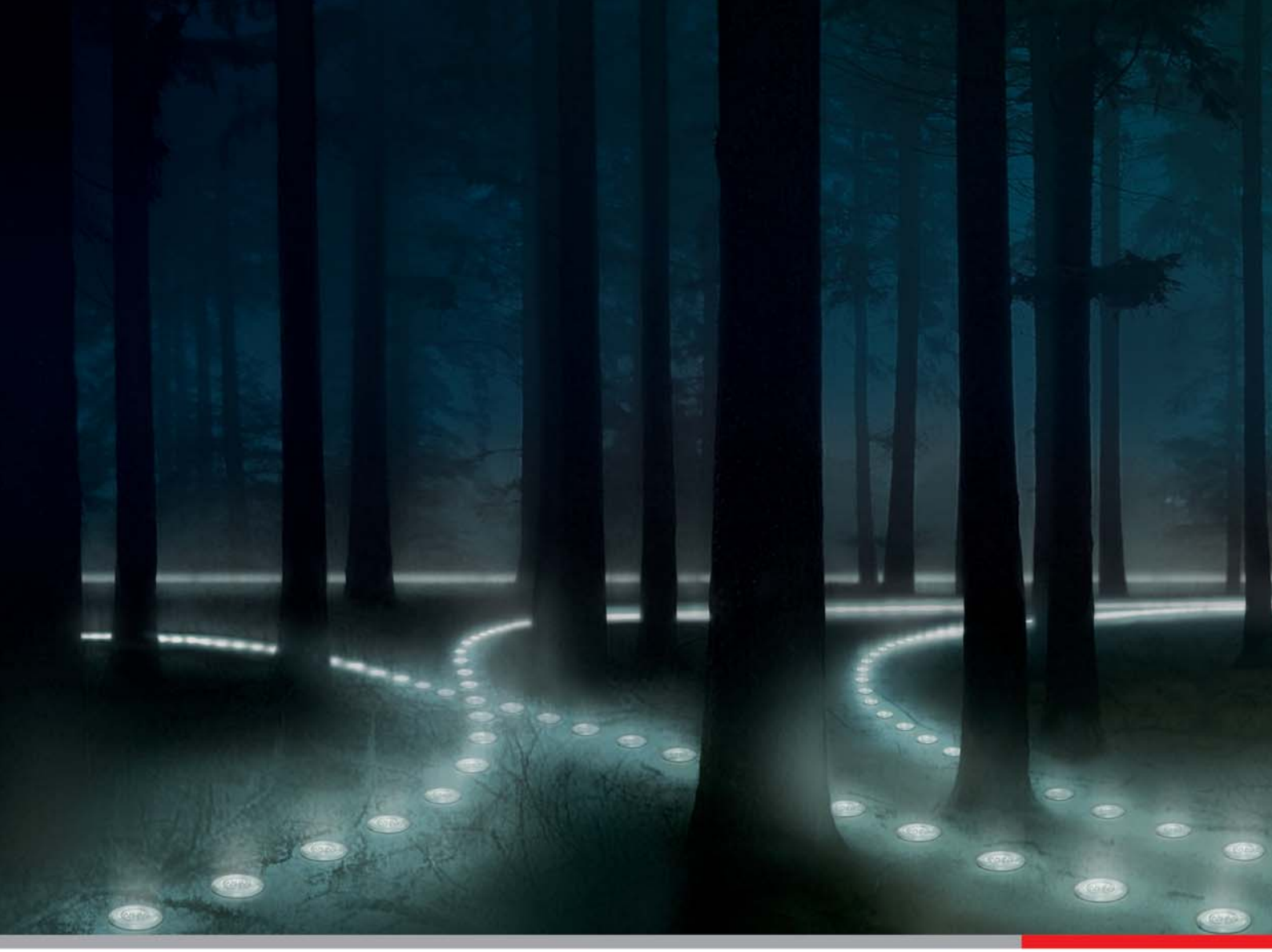

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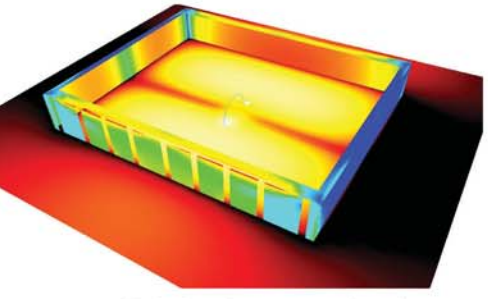

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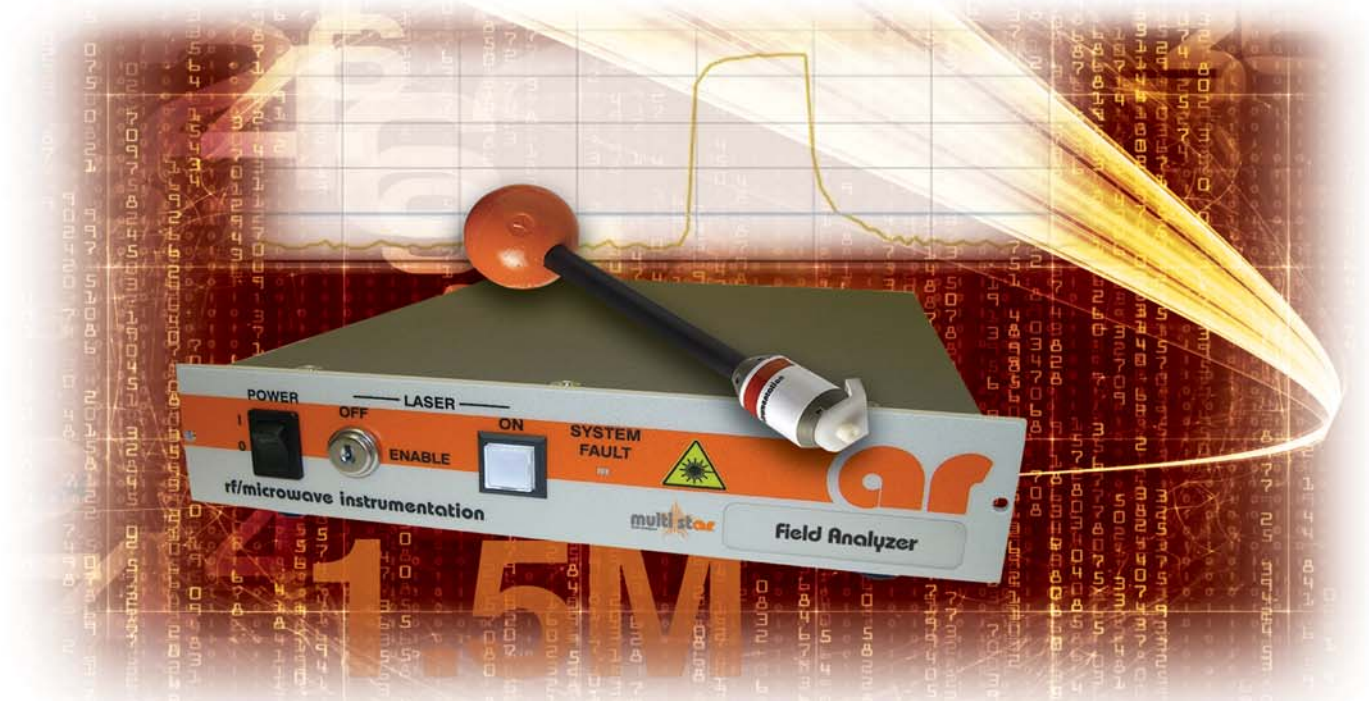

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